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PERT AT WESTERN UNION

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INDEX

For contents of Technical Review
published previous to 1958, see
separately printed Index for
1947 — 1957

For Index January 1958 — October 1959
see Vol. 13, No. 4, October 1959

For Index January 1960 — October 1961
see Vol. 15, No. 4, October 1961

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Technical Review

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CONTENTS

PAGE

E. R. Adamkiewicz, Engineer—Industrial Engineering Dept. and

A. J. Marra, Methods Supervisor—Office of Vice President and Comptroller

PERT—A Program Management Tool

THE accelerated pace of science and technology in today's Space Age has challenged the capacity of top management in government and industry to plan and control complex programs accurately. One of the latest management control techniques developed to assist managers in scheduling and completing projects "on time" is PERT, Program Evaluation and Review Technique. While it was originally developed for use by government agencies, it is now being applied in industry.

How PERT Started

The adoption of PERT as a Time-Cost-Planning-Measurement tool began in 1958 when the United States Navy Special Projects Office, Bureau of Ordnance established a research team with the management consultants of Booz, Allen, and Hamilton. The object was to develop, test, and implement a methodology for scheduling the Polaris program. It sought to provide management with an integrated evaluation of:

(1) current progress and outlook for accomplishing the objectives,
(2) validity of established plans and schedules for accomplishing total program objectives, and
(3) the impact of proposed changes to established plans.

PERT was implemented on the Polaris program and is credited with enabling the Navy to roll out an operational ICBM—firing nuclear submarine two years ahead of schedule. The original concept of PERT has since been extended to hundreds of management situations in defense and industry.

What is PERT

PERT is a management control tool for defining the objective and integrating what must be done to accomplish the objective "on time." It is a statistical technique for quantifying knowledge about uncertainties faced in meeting program deadlines. It focuses management's attention on danger signals or bottlenecks which require remedial decisions. It indicates areas of effort where adjustments in time, resources, or technical performance might improve the capacity to meet major deadlines.

Two fundamental characteristics of the PERT concept differentiate it radically from previous management systems. These are:

(1) the planning techniques employed and, if required
(2) the use of large digital computers for data processing and computation of management statistics.

The basic innovation in the PERT planning technique is the use of network diagram analysis.

The primary weakness of conventional planning and scheduling techniques is the inherent lack of ability to adequately identify critical and non-critical areas, and to measure the impact of changes on the total program.

PERT has been proven to be so valuable that it appears that its use will be mandatory in all future Air Force contracts.

PERT at Western Union

Considerable progress has been made in initiating the use of PERT in Western Union. PERT charts have been developed and submitted as part of the proposals to prospective customers. The purpose of these charts has been two-fold; first, to show the feasibility of meeting the operational deadline and secondly, to provide a clear picture of the "plan of action" Western Union will use. PERT charts were prepared for and included in the Jet Propulsion Laboratories proposal, U.S. Weather Bureau study, NORAD Project, Defense Communications Agency proposal, NARE (Navy Automatic Relay

Equipment) proposal and others.

The basic foundation for PERT is the establishment of a flow chart or network depicting the entire project in considerable detail. All of the individual tasks needed to complete a given program must be visualized as milestones or events. These milestones are points of accomplishment in the program.

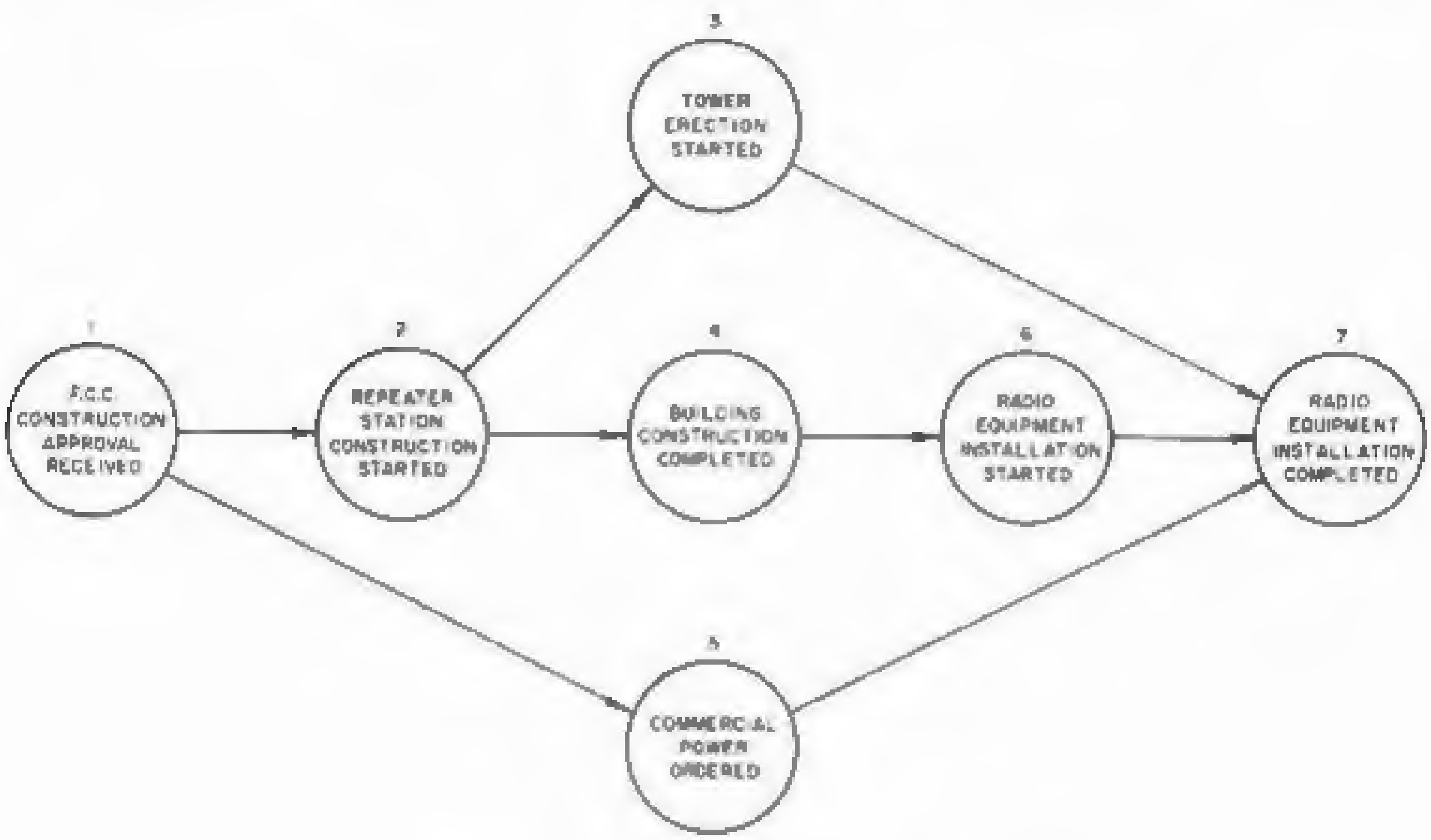

Figure 1. A Simple PERT Network

Figure 1 illustrates a simple PERT network. The circles represent events, or milestones and the lines between them represent activities or the work necessary to reach each event. In this example, activities leading to events 3, and 4 cannot be started until event 2 has been completed. Similarly, the final accomplishment of event 7 depends on completing activities 3-7, 5-7, and 6-7. Some activities such as 2-3 and 2-4 do not depend on each other and can be accomplished simultaneously. This illustrates the main advantage of PERT diagrams — they show what has to be done in sequential order. The inter-relationships between activities would not be as obvious on a conventional bar chart.

Team Approach

In developing PERT charts the team approach is used. A team is composed of individual contributors in the line organizations who have direct responsibility for the project using this technique. For each event the PERT Consulting Engineer asks the following questions of the team: (1) What happens just before this? (2) What happens just after this? (3) What else can be done at the same time? Experience has shown that one of the most productive results of PERT as a planning tool, is the tremendous amount of communications made possible, not only between different functional groups but also within functional groups. The logic of planning with PERT simply points up the potential problem spots and forces the need for making decisions. During the first meeting, project objectives are defined and the broad or general network for the program is developed. This is followed by individual conferences of the separate groups or individuals to work out the details of their areas of responsibility. What the members of the team are

really doing is hammering out decisions at a remarkable pace—not just what and how things will be done tomorrow or next week, but what, where, why, and how things will be done in six months or a year or more later.

Time Estimating

After the network has been developed, time estimates are prepared on a three-way basis, i.e., optimistic, most likely, and pessimistic elapsed-time figures. These are estimated by the person or persons most familiar with each activity involved. The three time estimates (usually given in weeks) serve as a gauge of the "measure of uncertainty" of the activity. The spread of these points is assumed to be 99 percent of the probability distribution.

Figure 2 illustrates a distribution curve used to describe the uncertainty of the three estimated time figures. The points T_O (optimistic time) and T_P (pessimistic time) denote the two extremes while T_M is the most likely time. With these three time estimates, a statistical expected time, t_e, is calculated from the formula:

$$t_e = \frac{T_O + 4T_M + T_P}{6}$$

This formula, although arbitrarily determined, has been found to be a satisfactory approximation of actual conditions.

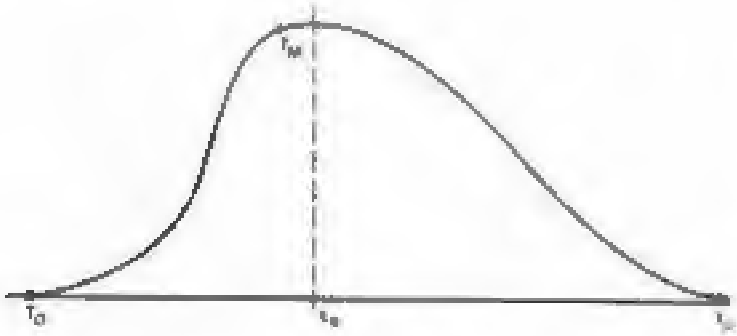

Figure 2. Distribution Curve

The way in which the three times are distributed is very revealing and helpful in identifying the nature of the problems. Three time estimates T_O, T_M, T_P such as 2-4-18; 5-6-7; and 1-7-7 all have a statistical expected time, (t_e), of six weeks, but each one tells a significant story—even before mathematical methods are employed. When all the time estimates are completed, then a time analysis is performed either by hand or with a computer, as the situation requires.

Engineers in the past were seldom called upon to estimate in as much detail and over such a prolonged period. With PERT, not only is a wealth of estimating data developed, but more important, it is retained. This alone gives the individual contributor a valuable tool for improving his time estimates.

Network Analysis

In the development of the first network, the program is planned in the most ideal way; very little, if any, risk is involved. Calendar dates are forgotten and all events in the program are planned in a clear-cut, technical, sequential manner.

The statistically expected time required to complete the project in the first analysis may differ substantially from the required time. If the program must be shortened to meet either a customer specification or the Marketing Department's estimate for a successful bid a re-analysis of the plan is made.

The key to shortening a program is re-planning. Several basic approaches can be tried:

1. Eliminate activities
2. Put series activities in parallel
3. Add Resources (Men, Money, Materials and Equipment)

To be specific, time can be saved by proceeding directly from the design stage to building the prototype; this eliminates construction of a breadboard. However, there is some risk involved which must be considered before a decision is reached.

An example of paralleling activities which will reduce the lead time of procurement can be shown this way: By using a preliminary bill of material from which parts are ordered, the procurement activity can run parallel to the preparation of the final drawing effort. Here again, additional cost and risks are assumed since some parts may become obsolete by changes. Overtime is usually the first resource to be applied to shorten a schedule. In many cases, when a program is found to be behind schedule, everyone

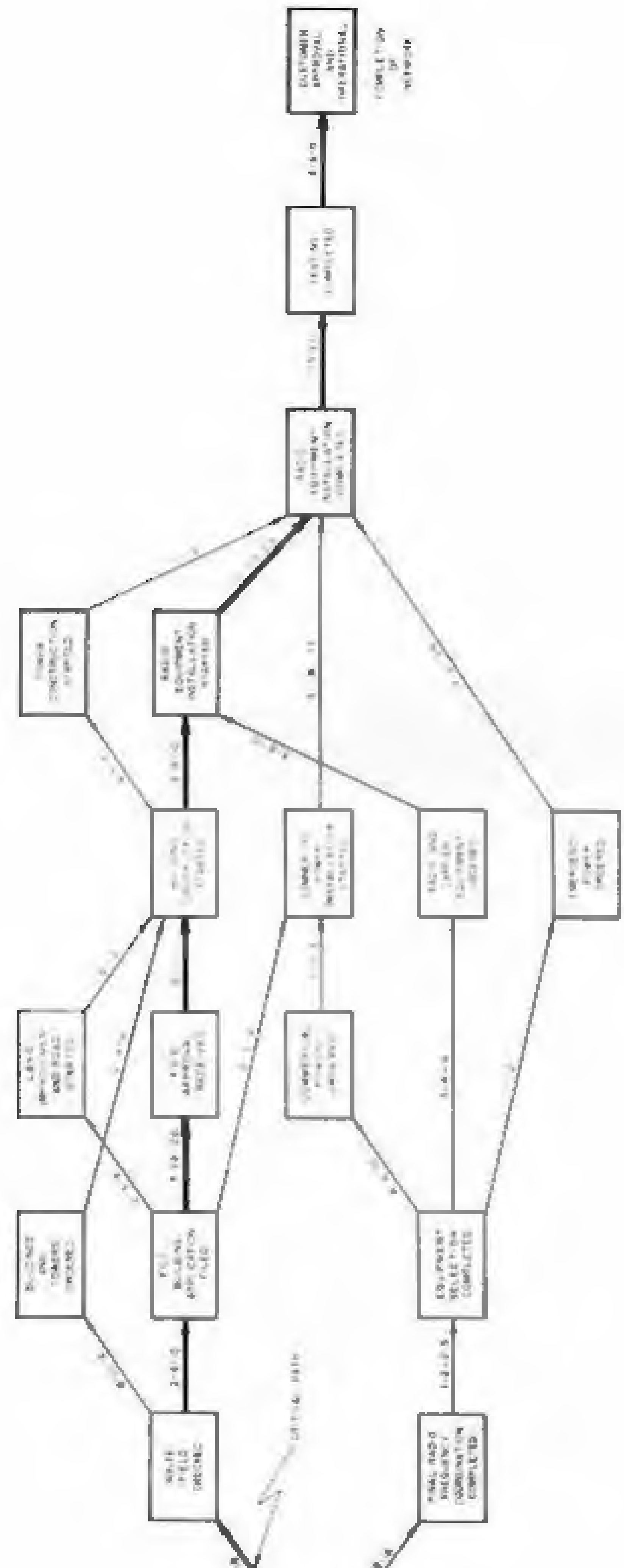

Figure 3. PERT Network for a Current Project

concerned is placed on overtime with a subsequent waste of most of the effort. The PERT method points out the critical activities where additional manpower will do the most good.

A condensed version of the PERT network, which has been prepared for an actual program, is shown in Figure 3. All times are indicated in weeks; the critical path is drawn as a heavy line. Times such as (0,0,0) indicate a constraint which means the preceding event must be completed before the next event can start.

The Critical Path

In any program, whether it is building a missile or a radio relay station, only 10 to 20 percent of the activities involved control the time required for the entire project. The longest path which connects the start of the program with the objective is known as the Critical Path. From the summation of expected times, (Σt_e), the Critical Path through the network is calculated. Any delay or speeding up of the activities on the critical path will affect the final completion date of the project.

The first step in determining the critical path is to convert the three time estimates to a single time called the "Expected Time" (t_e) for an activity. The expected time, t_e, has a 50 percent probability of being attained, as shown in Figure 2.

By similar calculations the Earliest Expected Date (T_E), the Latest Date (T_L), and the Slack Time (S_L) can be computed for each event. The Earliest Expected Date (T_E) is the summation of the Expected Times (Σt_e) of all activities on the longest path from the first event, converted to a calendar date. The Latest Date (T_L) is the latest calendar date an event can be completed without affecting the schedule.

Slack Time is the difference in time between the Earliest Expected Date and the Latest Date an event can be completed, $S_L = (T_L - T_E)$. This can be positive, zero, or negative.

Common PERT practice also makes use of a statistical concept called Variance (V), as a means for predicting the probability of completing any event "on time." Variance is the square of the standard deviation and is calculated according to the following:

$$V = \left(\frac{T_P - T_O}{6}\right)^2$$

Diagrams many times as complicated as the one shown in Figure 3 are not unusual and planning them without oversight is 90% of the battle. The PERT chart which is being used to monitor progress on a current project consists of 78 events and about 125 activities, which is considered to be a small, simple network.

Western Union Applications

The PERT analysis covering the Western Union Radio Beam Expansion Project will be used to determine manpower requirements for acceptance testing; PERT is also being used here to predict operational dates.

Detailed networks for the Broadband-Switching Program have been prepared. To simplify the development of this complex PERT chart, sub-networks have been employed. Standard PERT subnetworks, which may be used again and again, have been developed for the Purchasing and Specifications Writing functions. Only the time estimates on the sub-networks are changed depending upon the modifications necessary for a particular job. The detailed PERT chart of the Broadband Switching program has 340 events and about 600 activities and is still growing as work continues.

PERT on the Computer

Networks up to about 100 events can be worked out quite rapidly by manual methods. However, a computer is most desirable, if not necessary, for larger networks. Computer application makes it possible to retain arrangement and printing of data in many ways for analytical purposes.

Network information is entered on activity forms and sent to the System IDP Center where the information is keypunched on cards and properly assembled for processing in the computer.

The Western Union Telegraph Company elected to employ the available IBM 650 Computer to analyze the networks used in the PERT system. This was done with the knowledge that the 650 computer was not generally considered as having sufficient capacity to handle large scale PERT networks. For this reason, it became necessary to develop new techniques for the achievement of the final results. The new techniques permit handling PERT charts of any complexity on this computer and represent a definite contribution to the art of program management.

The actual solution to the greater capacity problem involves the specific insertion of "dummy" events and division of the calculations into three distinct programs as follows

1. Sequencing of the activities for processing in programs 2 and 3,
2. Calculating the Earliest Expected Time and Variance,
3. Calculating the Latest Time and Slack Time.

Sectionalizing the PERT Chart

After designing the PERT chart, the PERT Consulting Engineer counts the number of activities in the network. If the number exceeds 285 activities, the PERT chart must be divided into sections for processing in the computer

The network is sectionalized for Program 1, as indicated in Figure 4, by drawing a vertical broken line through events at approximately every 285 activities such as Reference A and Reference B. If it is necessary that this vertical broken line cross an activity line connecting two events rather than going through an event, a dummy event shown as a diamond shaped symbol is inserted at this intersection. This dummy event is numbered in the same manner as other events, but starts with the digit 9 as indicated at Reference A.

In posting the events that are intersected by the vertical broken line, they are treated as successors in the first section and as predecessors in the next section, with separate computer processing for each section.

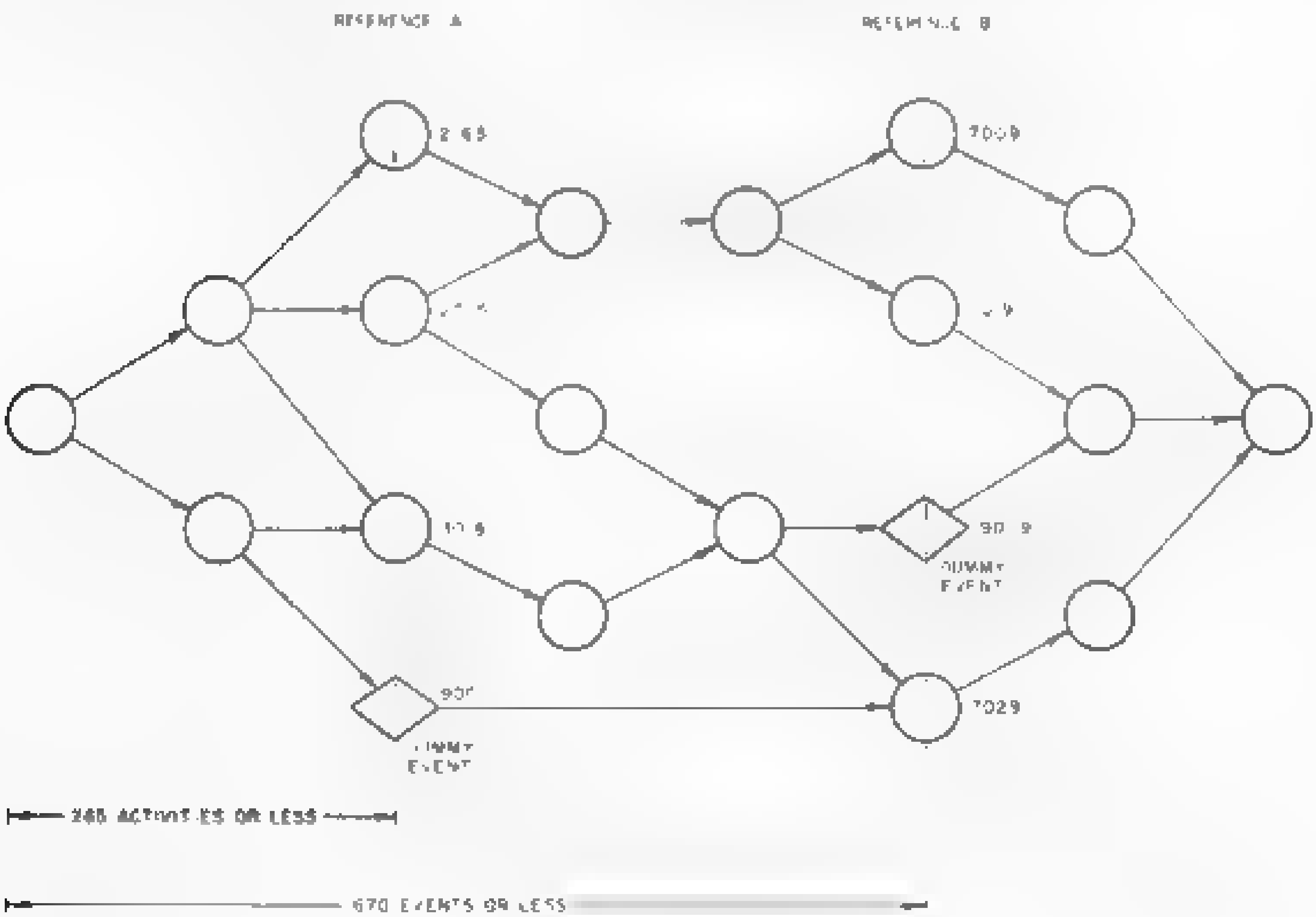

Figure 4. A Sectionalized PERT Network with Dummy Events Inserted

Designation for Programs 2 and 3

When the sectionalizing of the network for Program 1 is completed, the network is then examined to locate the vertical broken line or lines which will divide the overall network into sections of approximately 670 events or less. This number is the limitation of events which can be processed through Programs 2 and 3 on the computer. All the events on this designated line, Reference B, including the diamond symbols (dummy events) are coded to end with the digit 9 as indicated. This method assures an unlimited number of activities and events which can be processed through the computer.

Processing Program 1

While processing the first section of activities in Program 1 (Sequencing of Activities), the computer will punch the following types of cards, each properly coded to expedite proper grouping for subsequent handling

1. Event table in numeric sequence for Program 2,
2. Sequenced Activities for Program 2, i.e. left to right on the PERT chart,
3. Sequenced Activities for Program 3, i.e. right to left on the PERT chart, if sufficient information was available for completing this calculation,
4. Incompleted calculations for inclusion in the next section of Program 1 to permit further sequencing of activities for Program 3.

This procedure differs from the normal method of handling PERT on a larger computer only in that it is broken down into sections. It specifically provides for a "carry-over" to permit processing larger problems than could be handled on a single pass basis.

Processing Program 2

Program 2 utilizes both the event table and the proper sequenced activities from Program 1. Using these data calculations, for the Earliest Expected Time (T_E) together with the Variance (V), are made for each event. Each section is calculated independently with a carry-over into the next section of the run for each event ending in the digit 9. Here it should be pointed out that the success of using the 650 computer for a large problem results from the simple method of sectionalizing, the wise use of code 9, and making the Program 2 calculations for all sections of the network before attempting to calculate the Latest Time (T_L) and the Slack Time (S_L).

Processing Program 3

The results of Program 2, together with the appropriately sequenced activities from Program 1 are processed in Program 3. During this program the calculations for Latest Time (T_L) and Slack Time (S_L) will be made. A final answer including Earliest Expected Time, Latest Time, Variance, and Slack Time will be punched for each event in the network As in Program 2, provisions are made for a carry-over between sections.

After processing all sections through Program 3, all the final event cards must be sorted in one column to extract all dummy events starting with the digit 9. The remaining cards can be used to produce various reports requested by the PERT Consulting Engineer. Generally, reports are made on a bi-weekly basis; however, intermediate reports can be requested as required.

Every two weeks the PERT Consulting Engineer reviews the network and checks with the individual contributors as to what events have occurred. Special attention is given to the activity times that lie along the critical path and if changes in the plan are indicated, this is also noted.

Conclusions

It is conceivable in the near future as PERT applications become firmly established in Western Union, that manpower scheduling and even cost plans can be included in the network approach. However, the addition of material, overhead, administrative, and contract cost to provide the ability to forecast dollars vs. time by activity is not simple. These applications are currently under study and development by several companies and agencies.

Acknowledgements

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Mr E. R. Adamkiewicz is an Engineer in the Industrial Engineering Department as a member of the PERT staff. His duties include implementation of the PERT techniques on various Western Union projects.

Mr Adamkiewicz received a Bachelor of Science degree from Fairleigh Dickinson University in 1959. After a tour of duty with the Army he was employed by the Reynolds Metals Company. In 1961 he joined Western Union as a member of the Plant Standards and Controls groups.

Mr. A. J. Marra is a Methods Supervisor in the IDP Methods Bureau of the Comptroller's Department. He joined Western Union in 1950 as a draftsman in the Plant and Engineering Department. During the early period of his employment, he attended the School of Engineering at New York University. In 1959 he transferred to the Comptroller's Department, where he was assigned to computer programming and methods analysis work. He participated in the research and development of the Plant Management Control programs and the Microwave Calculations programs.

R. P. Stotz, Project Engineer—Voice and Voice-Record Services

Point-to-Point Subscriber Set

As described in the July issue, the entry of Western Union into the voice and voice-record field will be dominated by large installations comprising the Broadband Switching System. As a complement to such systems, however, there is a need for relatively simple and less extensive private-service interconnections, such as a low-to-moderate speed, voice-coordinated data and record service on a fixed point-to-point basis. This need arises from the fact that some users of communication services have fairly heavy sustained traffic between particular points and may consequently find the lease of an interconnecting facility on a full time basis more economical than the use of a public message switching network charging on a time-used basis.

To implement the required service it was necessary to develop a telephone terminal set, designed especially for point-to-point operation, which facilitated voice-coordination between the connected record-making equipments. To avoid distance limitations, signalling methods were arranged so that both physical and carrier sections could be interconnected. A suitable switch, incorporated in the device, would simplify alternate voice-record use while low maintenance, small size and long life was insured by the use of transistor circuits where practicable. Since no "central office" telephone equipment was available, all necessary control circuits had to be included in the basic terminal set. Performance specifications were laid down for procurement purposes; an agreement was made with North Electric Co. to complete the design on a commercial basis and to manufacture the units. The final result of this joint endeavor, is illustrated in Figure 1.

The Western Union Data-Voice Subscriber Set, obtainable in both wall-mounted and desk-type models, consists of two physical units: the telephone instrument, which contains the necessary voice and electronic circuits, as well as the switching controls as shown in Figure 2 and the power supply, which also mounts the switching relays and the output stage of the ringing circuits as shown in Figure 3. For primary power the set requires commercial 60 cps at 110 volts.

Circuit Description

The general circuit arrangement is shown in the circuit block diagram in Figure 4. The Voice portion of the Subscriber Set comprises a standard, high quality, telephone transmitter - receiver handset with four-wire connections. A "side-tone circuit" transfers a small amount of energy from the transmitter

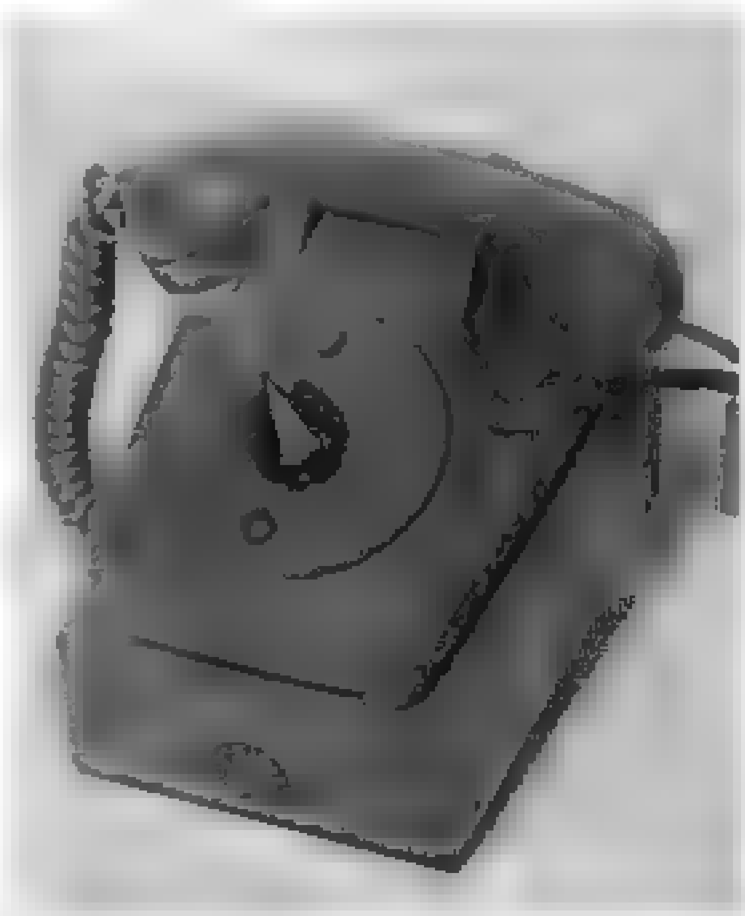


Figure 1 Point-to-Point Subscriber Set

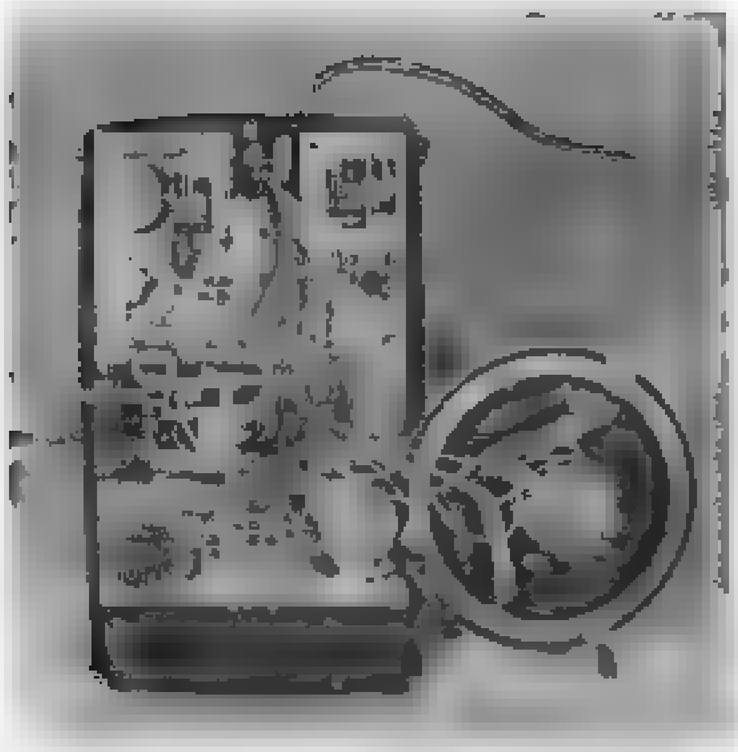


Figure 2. Subscriber Set Showing Printed Circuit Assembly

so that the user may hear his own voice in the receiver—a factor found to be of psychological importance rather than a technical necessity. Local transmitter battery is provided by the power supply.

The signalling circuit consists of a transistorized Hartley Oscillator resonating at a frequency of 1000 cps, for initiating connections. The tuned elements are temperature compensated for good frequency and level stability. When energized by the "Ring" push-button, the oscillator output is coupled through an emitter-follower buffer-amplifier and a transformer to the "Send" line, providing an "In Band" ring tone at a level of about 0 dbm.

On the receiving side, a transformer couples the incoming line signal to a limiter stage, tuned to provide maximum output at 1000 cps. The limiter is biased so that it will saturate at a very low level, and thus produce a constant output for input levels ranging from minus 30 dbm to 0 dbm. A second stage of amplification provides a low impedance current drive for a third stage. This stage is driven to saturation during a portion of each cycle and hence acts to introduce harmonics so that a mellower, more pleasing tone is emitted from a "ringing" horn. The horn, driven by a modified telephone receiver, is equipped for adjustment of the input level so that the sound output can be suited to individual requirements.

To prevent transient excitation of the ring tone circuits, a delay section has been introduced. Consequently, in order to produce a ring tone output, the 1000 cps signal must remain "on" for about 300 milliseconds.

Switching Circuits

A "Mode Selection" switch controls the operation of two switching relays contained in the power supply box. These relays transfer connections from the lines to the associated voice or record equipment. When the switch is in the "Phone" position, the signaling and telephone circuits are connected to the lines for conventional telephone operation. There are three "Data" positions on the switch. In the "DX" position, the receive and send line circuits are connected respectively to the corresponding terminals of the associated record equipment for "duplex" operation. The telephone circuits are completely disconnected. In the "SEN" position, the send line is connected to the "send" terminals of the data equipment, while the telephone receiving circuits remain connected to the receive line. In the "REC" position, the receive terminals of the data equipment are connected to the line while the telephone "send" circuit remains in operation. By virtue of these switching options and four-wire line connections, a station receiving record com-

Figure 3. Power Supply Unit with Switching Relays and Output Horn

munication can signal the sending station and give one-way verbal instructions without interfering with the transmission.

Operation

In the idle condition both terminals are normally connected as telephones, and initial contact is made by voice. During the preliminary "voice coordination" the desired data transmissions are arranged. As indicated earlier, selection of the DX position of the "Mode" switch at both terminals permits simultaneous record transmission and reception, provided that there is complete separation of the receive and transmit sections of the record equipment. When one-way transmission is desired, the sending party selects the "SEN" position while the receiving party selects the "REC" position. Should transmission be faulty, the receiving party can ring the sender and request re-transmission or further voice coordination. Routines for acknowledging such calls by manipulation of the data signals can be worked out by the users.

Associated Equipment

The Subscriber Set will accept any four-wire alternating current record device operating within the band limitation of the interconnecting facility. Digital transmission ordinarily must be converted to suitable alternating current by a modulator-demodulator. Western Union modems capable of converting teleprinter signals, IBM card punch, and similar data machine outputs are available for use with the Subscriber Set. At the present time, data speeds from 50 to 1200 bauds can be handled with non-synchronous modems. Similar modems for higher speeds up to 2400 bauds are expected to be available early next year.

Analog signals require no conversion, hence facsimile and similar devices may

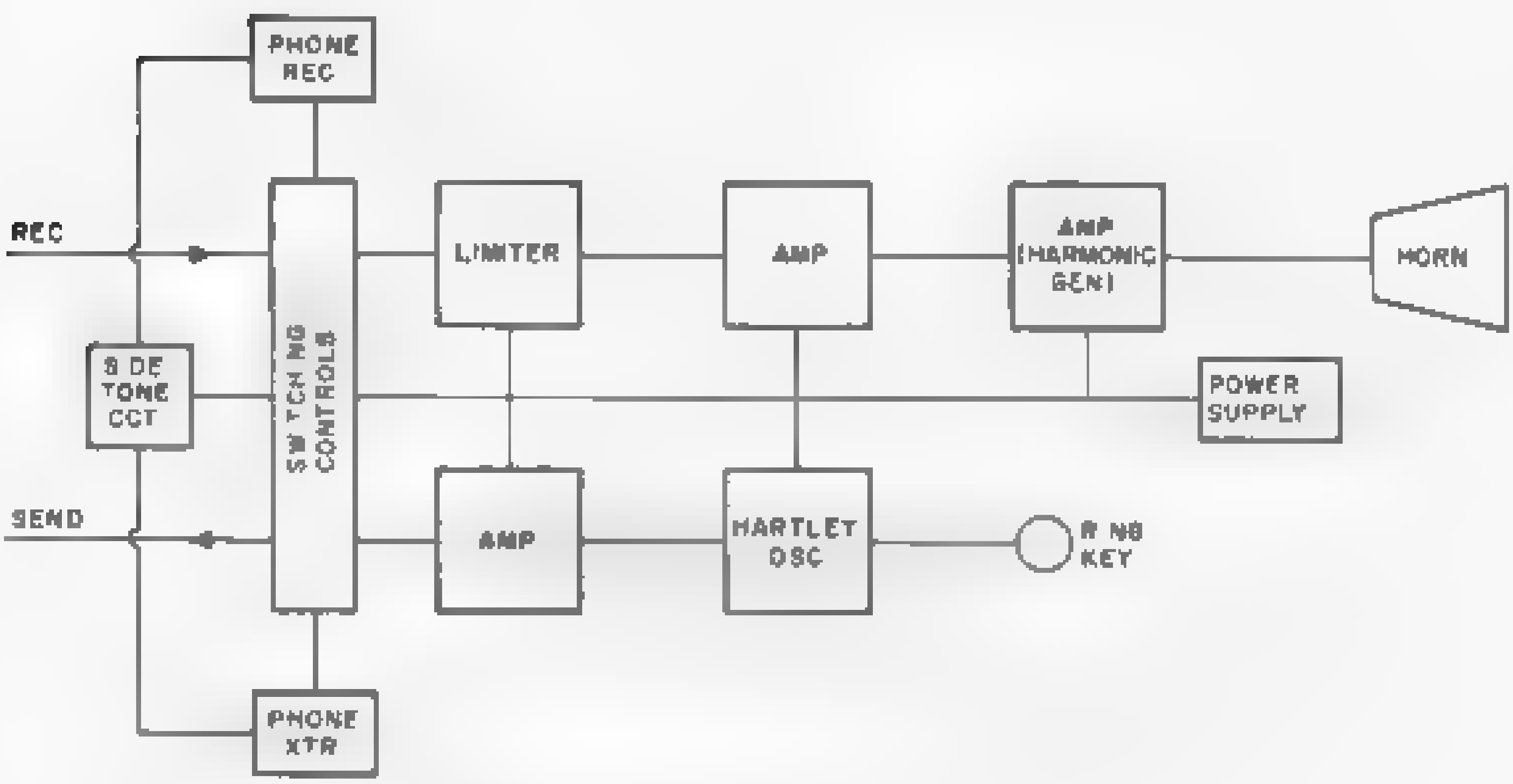


Figure 4. Block Diagram of Data-Voice Subscriber Set

be directly connected to the Subscriber Set. Unattended operation of the receiver, for either type of signals, can be accomplished with the aid of attachments which will be available soon.

Auxiliary Switching Capability

Although the inherent switching capability of the Subscriber Set is limited to a single unit of record equipment, an auxiliary switching assembly is available which will extend the switching capability to as many as four units. These may share a modem associated with the lines or not, as may be required. Need for more than four units sharing the same line facilities is believed to be unlikely.

Bridged Subscriber Sets

When multipoint circuits for voice use only are desired, relatively uncomplicated, hubbing arrangements may be employed where a system of code ringing selects the desired drop. On this type of interconnection all parties have unrestricted access to the circuit. The arrangement therefore would not normally be satisfactory for data use, since there is no protection against third party cut-in and consequent garbling of the data signals.

Bridged Data Drops

The use of balanced hybrid hubs permits bridging several "receive only" data stations along a circuit, provided that sending coordination and control is limited to two points furnished with telephone subscriber sets. In this arrangement the placement of the two cooperating control data stations is not restricted but the "receive only" drops must be capable of unattended operation.

Conclusion

It has been shown by the demand for such services that a leased communication facility, restricted to two high volume points, may be a considerable convenience, both from an economic and a service point of view. For data circuits, the added bonus of voice communications can contribute to efficient and safe operation. Voice coordination also tends to reduce the need for auxiliary equipment associated with automatic operation.

While the Subscriber Set is normally used to control voiceband services, wider bands could, of course, be readily substituted for the data interconnections. A wide field for the use of such circuits is expected when the broadband line facilities become available.

Mr. Ralph P. Stotz has recently been concerned with the development of voice-record services for Western Union. He started at Western Union in 1956 in the Specifications Engineering Section and later transferred to the Automation Application Section where he assisted in the development of Plans 57 and 59.

Following this he aided in the design of circuit switching cabinets used in Patron Systems.

He received his B.A. and B.S. degrees in Electrical Engineering from New York University. He is a member of the I.R.E.

A. W. Dickey—Cable Equipment Engineer

Two-Channel Multiplex for Italcable Company

CABLEGRAMS between United States and Italy have been transmitted over cable routes that pass through the Azores Islands for many years. The Italcable Company owns a cable that extends from Horta, Fayal; to Malaga, Spain; and then to Acilia, Italy, a coastal village near Rome. The Italcable Company operates the stations at Malaga, Acilia and Rome, but at Horta it has a contract with the International Communications which provides that all operations there be performed by Western Union personnel. The cable station at Horta is the terminal for the 1HO and 2HO Western Union cables. It includes facilities for interchanging traffic with three other cable companies besides Italcable.

The Horta-Rome cable was originally put in service in 1925 as a duplex single-channel facility. Signalling was accomplished by means of cable recorder code; all messages were manually repeated at Horta. Sometime later, two-channel duplex was established but this did not prove too satisfactory. Consequently in 1934, service was returned to single-channel operation which is still in use today. However, the operating practices have changed over the years because Western Union's transatlantic system became printerized (5-unit Baudot code) while the Horta-Rome section has remained on a cable code basis. In 1939 Western Union installed a translator at Horta which automatically converted the printer coded eastbound traffic into cable code, but westbound traffic remained manually transcribed i.e. read from a direct writer and manually perforated into 5-unit code tape.

In the early 1950's Italcable, with engineering assistance from the Research and Engineering Department of Western Union, substituted signal shaping electronic amplifiers for the mechanical hot-wire magnifiers and drum relays formerly used to receive the low level cable signals. These amplifiers stabilized operation; this was an essential step toward printerizing. This past summer the modernization program was completed, and again Western Union played the leading role in engineering and manufacturing the necessary terminal and repeater equipment to do the job.

In contrast to cable code operation which has provided a single 310 lpm traffic channel eastward, and a 340 lpm westward (650 lpm total duplex capacity), this new equipment will provide two printer channels eastward and westward with automatic switching to select particular stations and particular kinds of traffic, and the speed of each channel will be at least 200 lpm (800 lpm duplex capacity).

The equipment is custom-made to suit conditions peculiar to Italcable's requirements. Although some of the most modern transistorized selecting and switching circuitry is employed, the synchronizing and phasing (correcting) provisions are basically the same as those in Italcable's synchronous cable code system. This system operated on a 30 cps time base comprising a 30 cps vacuum tube controlled tuning fork. The multiplex distributors, fitted with silver segmented face plates, are driven from this 30 cycle source. Various gear ratios are provided to produce signalling speeds from 200 to 300 lpm per channel in steps of 25 lpm.

Eastbound messages from New York can, by a simple two-character prefix, be routed to Malaga or to Rome. At Malaga they may be routed to either a full rate or deferred drop. Westward messages from Rome can likewise be routed to either Malaga, Horta, or New York.

Most of the apparatus is mounted in rack cabinets constructed as shown in Figures 1 and 2. The various panels are pull-out drawers which can, when necessary, be rotated for easy access to both the bottom and top of a drawer in checking and maintenance. Multiplex distributors, start-stop distributors, channel re-

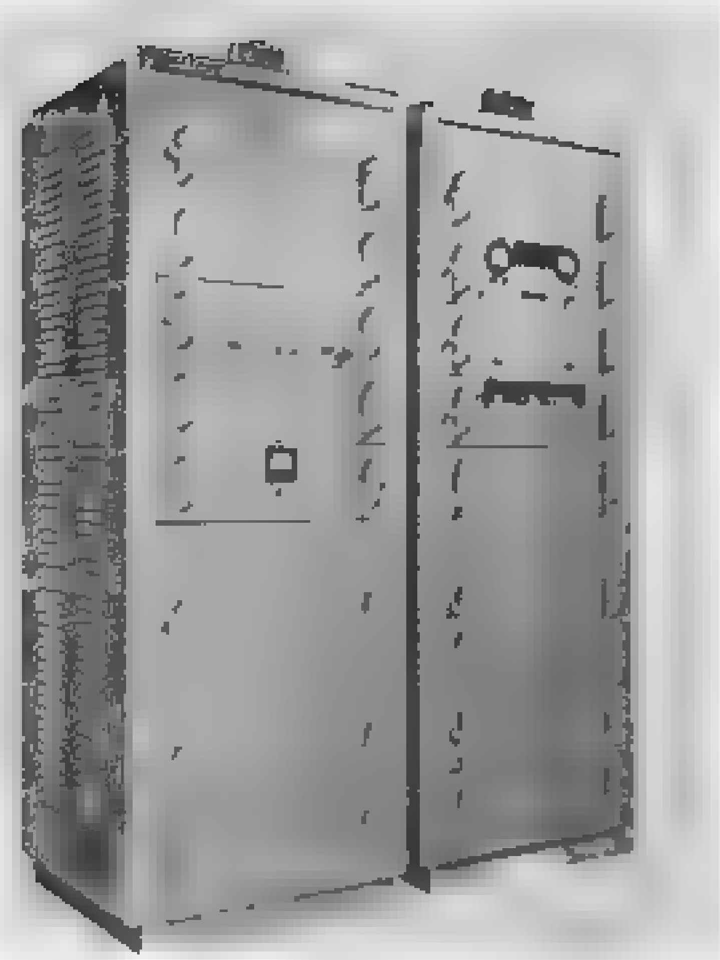


Figure 1 Rack Cabinets at Horta

peaters, and switching selectors are all in these cabinets. Two cabinets are installed in each station except Rome where there are two units each of, Model 5724 tape reperforators, Model 28 (LXD) distributor-transmitters, and the printers on the operators' tables. The monitor printers at Malaga are the Model 28 type in consoles; those at Horta are Model 2-B. The drop positions at Horta and Malaga are equipped with Model 28 (LPR) typing reperforators.

Initially the interchange of traffic at Horta will be by "torn-tape" routines. Later on apparatus for fully automatic handling may be added if experience proves it to be justified.

Planning of system operation, design of all circuitry, and specification of electro-mechanical apparatus was accomplished within the Cable Equipment Engineer's division. This group conducted tests in the laboratory and in the field. Various component apparatus designs and cabinet layouts were prepared by the Telegraph Equipment Engineer's division. The Plant Department handled the manufacturing in the shops at Chattanooga and New York, and installed the equipment at Horta.

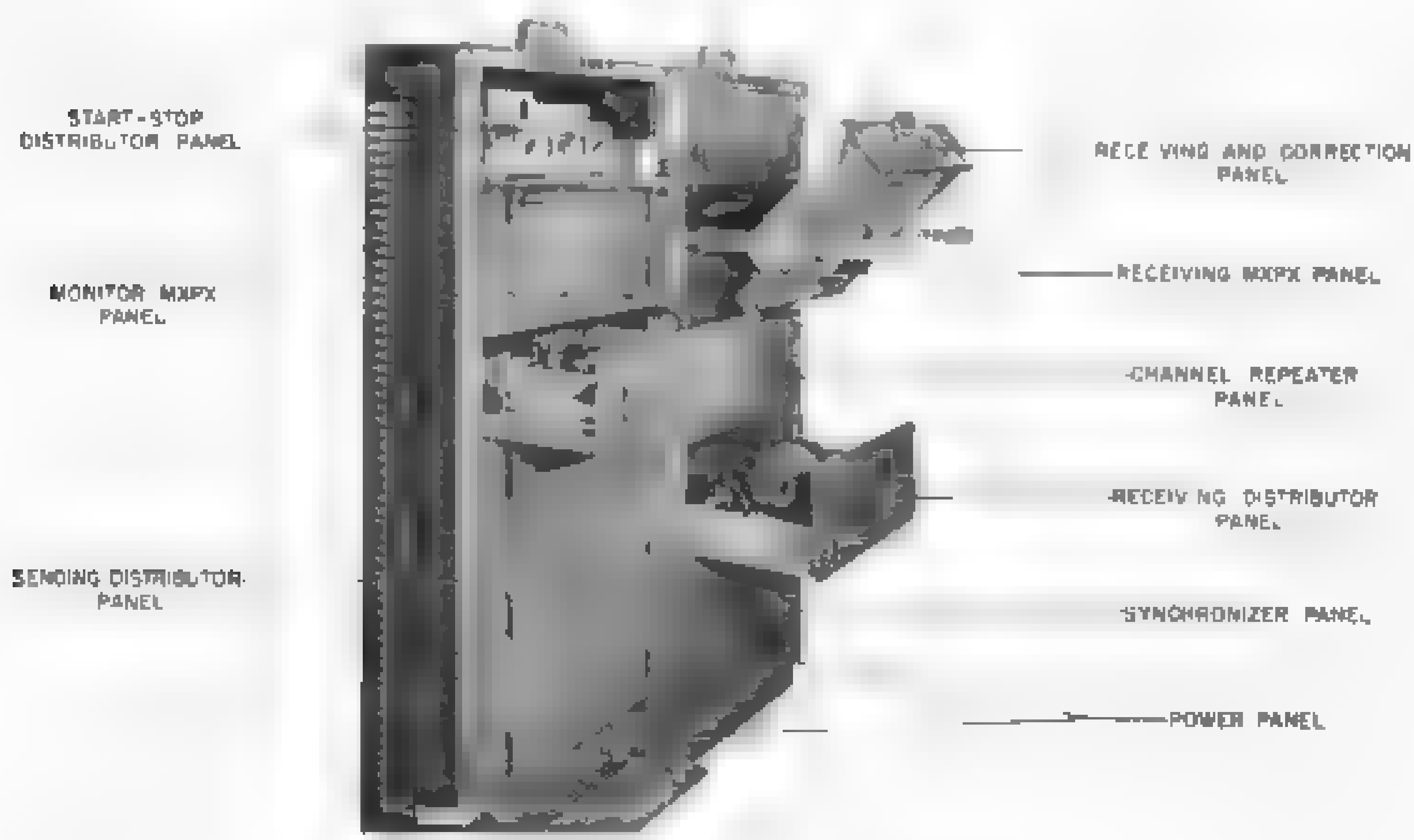


Figure 2 Rack Cabinets at Acilia

E. J. Chojnowski, Senior Project Engineer, R. & E. Project Office—Comlognet

Digital Phase Corrector for Synchronous Transmission

Introduction

WITH the rapid growth in data processing applications and the wide technical advances in the digital computer art, new and increasing demands have been made on data communications. The capacity of computers to digest tremendous volumes of data in fractions of seconds reflects the need for high speed data inputs to supply the computers with raw data for processing.

In many data processing applications data is collected from remote locations by means of high speed communications links established between remote data handling equipments. To insure the accuracy of data received from these remote sources, some form of accuracy checking is generally used to protect against errors in transmission. This is commonly provided for by using redundant error checking codes. The simplest of these includes an additional bit per character for character parity checking. An improved arrangement includes a block parity check as well. The application of both these checks is commonly referred to as vertical and horizontal checking.

Synchronous Transmission Systems

The use of redundant codes in transmission effectively reduces transmission efficiency, thus requiring additional bandwidth in communications facilities for a given data transfer rate. To compensate for these losses a synchronous mode of transmission can be utilized which does not require additional redundancy such as that needed with start-stop systems. Start-stop codes require at least two additional elements of redundancy for synchronizing purposes. These contribute nothing in the way of information or accuracy checks yet effectively reduce the data transfer rate. Although synchronous transmission systems are generally more costly than start-stop systems, they are ideally suited for high speed continuous data transmission

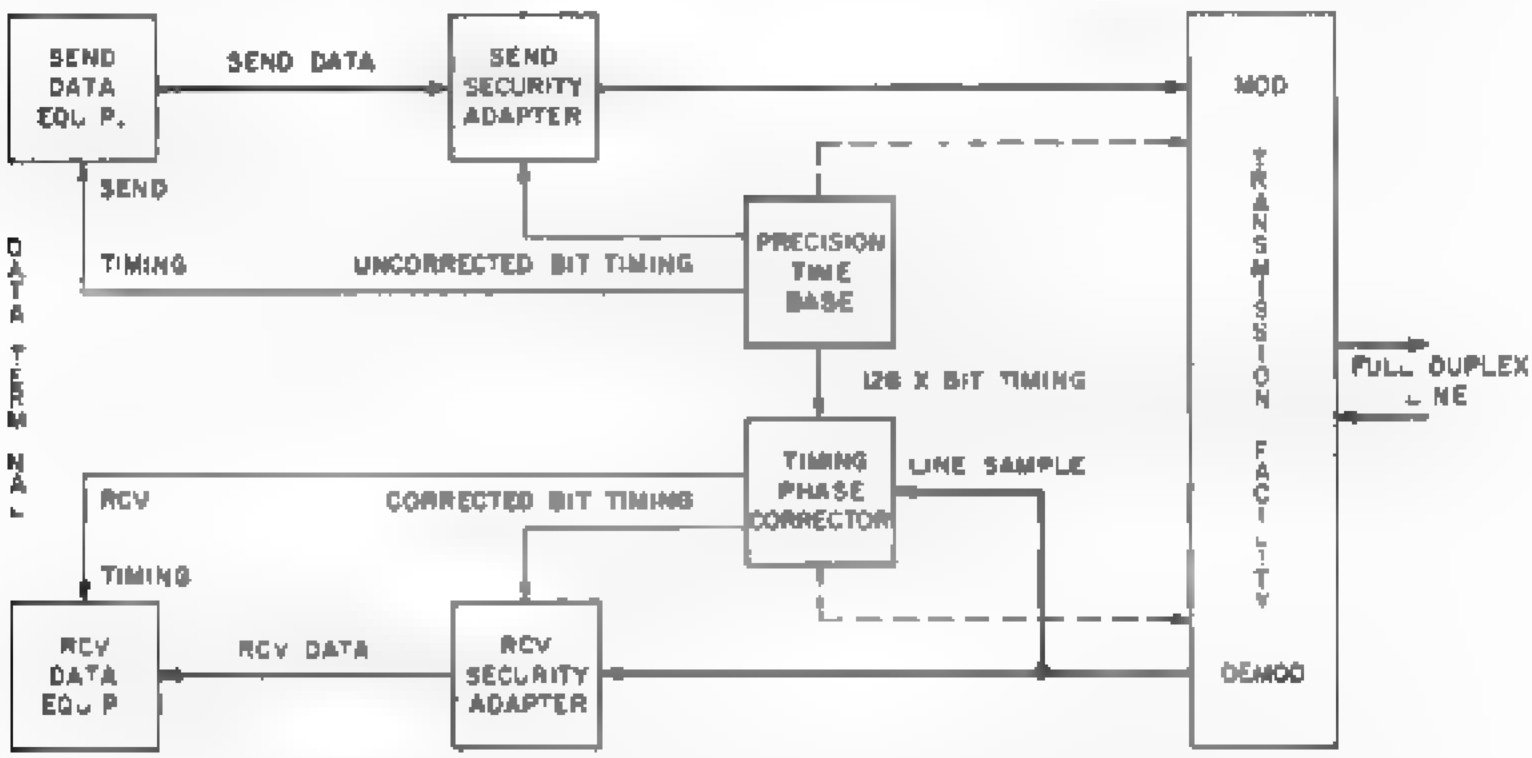
Comlognet Communications Facility

In Western Union's recent development of the Air Force Data Communications System DATACOM (Phase I—Comlognet) a bit serial synchronous transmission scheme was adopted in establishing high quality communication links between Comlognet Switching Centers and their tributaries. These links operate at any one of a variety of transmission rates from 75 bauds to 2400 bauds in multiples of 75 x 2^n bauds. Full duplex facilities are used to provide a maximum data transfer at any given baud rate and to provide a means for coordinating accuracy checks between remotely connected data terminals. Thus with the use of duplex facilities the Comlognet system is provided with a completely automatic error checking and correction capability in transmission.

Timing for the synchronous transmission facility is obtained from highly stable crystal oscillator sources at each data terminal location. In the switching center, a common master oscillator supplies timing for the entire center. The oscillator drives a binary frequency divider chain to derive fixed bit timing at selected baud rates for the transmitting apparatus. Fixed timing (at 128 times the bit timing rate) taken from the same chain

is used to clock a Timing Phase Corrector associated with each receive line. Its function is to provide corrected bit timing for the receive data equipments. A block diagram of the timing arrangement for a typical Comlognet outstation data terminal is shown in Figure 1. In this timing arrangement the send station is considered a master and uses its own fixed timing for clocking the send data. The receive station timing is a complete slave to its remotely connected send station's timing ing crossovers of the incoming line signals and uses this information to correct the phase of the local timing to provide the proper relationship for sampling these signals.

The design of the Digital Phase Corrector used in Comlognet was influenced by a number of system design requirements. Of these, the more important were the result of having to operate with secured, i.e., encrypted, communication links. The synchronization of security equipments necessitates the prior estab-



NOTE - DOTTED LINES INDICATE TIMING FOR SYNCHRONOUS MODEM EQUIPMENTS WHEN USED

Figure 1 Block Diagram of Timing Arrangement for Comlognet Outstation

Digital Timing Phase Corrector

The Digital Timing Phase Corrector furnishes the basic means for synchronizing remotely connected data equipments. Its only requirement is to establish and maintain bit synchronism. (Character framing is automatically established by the data terminal itself, once bit synchronism is established. Framing is effected on recognition of a unique idle line character pattern which is used to establish the bit positions of characters and to synchronize a character bit counter which subsequently identifies the received data characters.) It determines the phase of the received bit timing by observ- lishment of bit synchronism between remote terminals. Consequently, bit synchronization has to be effected on random bit stream without benefit of character identity, that is, intelligence is not recognized by the data equipment until the security equipments have been synchronized. Another requirement of the system is that synchronism of the security equipments be maintained for periods of at least one hour during interruptions in the communications facility. To meet this requirement a Digital Phase Corrector must be capable of remembering the position it assumed at the time of the circuit

interruption. The only change in phase between the timing signals of two disconnected stations will result from the natural drift of their crystal oscillators and is entirely dependent on their stabilities and setting accuracies. The maximum limit, in the allowable phase shift between the two timing signals resulting from drift, approaches one half bit. At one-half bit in either direction synchronism is lost in the security equipments.

Optimum Phasing

The degree to which the theoretical maximum phase shift can be approached is dependent on the correction characteristic of the Digital Phase Corrector. To reach this theoretical limit, the Corrector must be capable of recognizing phase errors of up to one half bit in either direction and be capable of selecting the shortest correction path to the in-phase position when line signals are restored. This means it will always make the minimum phase correction in reaching the correct timing position and will never shift the phase by more than one half bit, relative to the line signals.

To guard against corrections on spurious noise signals when the transmission carrier is interrupted, the Comlognet modems are equipped with space-hold circuits for loss of carrier protection which disable the sampling input circuit to the Timing Phase Corrector during this period

Optimum Sampling

To minimize transmission errors resulting from noise in the communications facility, a Phase Corrector should also be capable of providing timing that samples the bit in the center even with biased line signals.

An optimum Phase Corrector, as here defined, is one that is capable of correcting unambiguously on random bit stream and of providing center sample timing. On random bit sampling, the Phase Corrector should be capable of correcting unambiguously on line signals with up to 50 percent total bias. The signal itself, with 50 percent bias or over, contains an ambiguity. As an example, 60 percent marking bias may well look like 40 percent spacing bias in a pure random bit stream.

Correction Theory

The Timing Phase Corrector described here provides both optimum sampling and optimum phase resolution. It performs phase correction by digital means upon sampling line signal transitions. Center sampling is effected by using both positive-going and negative-going transitions in determining phase error. A Phase Corrector of this type is referred to as a two-transition corrector

Correction is accomplished in incremental steps by the addition or substraction of clock pulses at 128 times the bit timing rate. These pulses are fed to a 7-stage binary divider chain, referred to as a Bit Timer. The output of this chain yields the corrected bit timing for the data terminal receive apparatus. The effect of adding or subtracting pulses in the Bit Timer is to advance or retard the phase of the corrected bit timing in increments of one part in 128 of a bit time.

Measuring Phase Error

The phase error between the incoming line signals and the corrected timing is measured by counting clock pulses at 128 times bit timing in the intervals between line transitions and the probe points of the corrected bit timing signal. Two successive intervals are added, taking into account both the positive and negative line transitions.

The in-phase relationship between line signals and corrected bit timing is that which provides optimum sampling of data signals. This position is recognized by the corrector when the two successive count intervals yield exactly 128 counts which is the equivalent of one bit time of counting.

Less than 128 counts indicates an error in phase in one direction, greater than 128 counts indicates an error in the opposite direction. Only the direction of the error is needed in determining whether to advance or retard the Bit Timer by one clock time. The direction of the correction is always such as to increase or re-

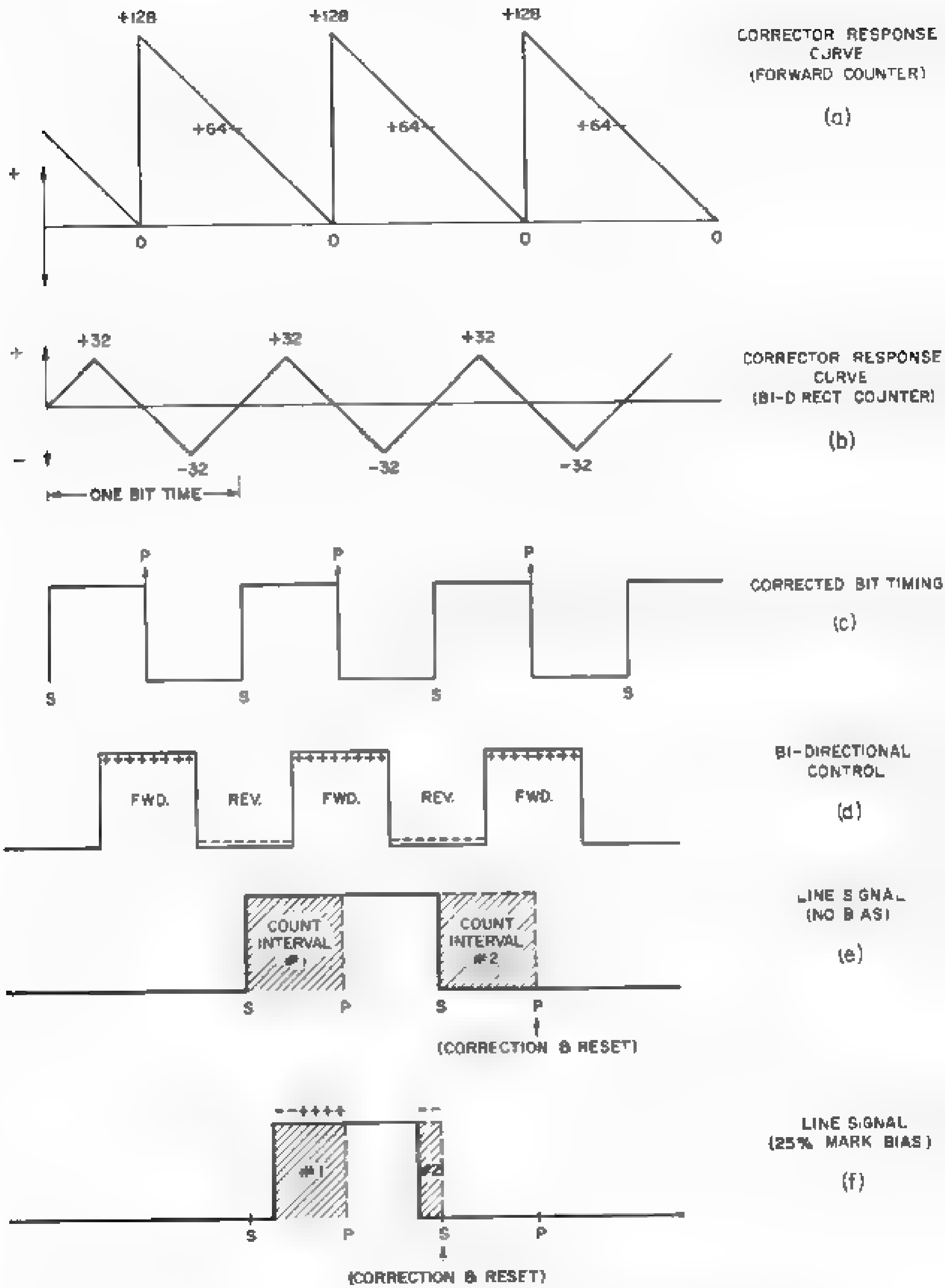


Figure 2. Response Curves for Phase Corrector

duce the count intervals on succeeding measurements until the summated intervals repeatedly yield 128 counts. An incremental correction is made on every pair of line transitions whereupon the counter is reset to zero and the process is repeated on the next pair of line transitions. The rate of correction is a function of the size of the incremental steps and the line signal transition rate. It takes a minimum of 64 pairs of line transitions to shift the phase of the bit timing by one half bit

A conventional forward counting binary chain of 8 stages, providing an excess of 128 counts, could be used for measuring phase error but, as will be shown, an ambiguity will result wherein two phase relations of line signal and corrected bit timing will exist that yield 128 counts. These positions are displaced from one another by exactly 180 degrees or one half-bit time and will produce stable operating points. This is a result of the response characteristic of the phase corrector as determined by the forward counter This is illustrated with the characteristic response curve shown in Figure 2(a) for a corrector using a forward counter

Interpretation of curve 2(a) requires a word of explanation. This response curve is so plotted that the intersection of a line transition with the curve indicates the algebraical number accumulated in the counter in the interval initiated by that line transition. Since two successive interval counts must be summated to determine the phase error, the number indicated by the intersection of a positive-going line transition has to be added algebraically to the number intersected by the succeeding negative-going transition in determining the total count on which a correction is made.

The slope of the curve in Figure 2(a) is inversely related to the direction of the counter which counts in a forward direction. Hence, a negative slope represents forward counting. The sign of the number is either positive or negative depending on whether it is greater or less than zero. Since 2(a) represents the response of a forward counter only positive numbers can be accumulated, thus the curve never goes below zero. The characteristic response curve is directly related to corrected bit timing in a fixed relationship as indicated by Figures 2(a) and 2(c). Line signals of 2(e) are variable and may have any phase relationship with respect to corrected bit timing. Figure 2(e) indicates in-phase line signals with no bias.

Examination of Figure 2(a) and 2(e) will show two possible ways in which a pair of line transitions may intercept the curve to obtain a count of 128. One is indicated by the positions of the line signal in Figure 2(e), the other is exactly one-half bit displaced from 2(e). Since the slope of the curve in Figure 2(a) is always the same and the counter can produce only positive numbers, the error indication will be the same in both cases.

Resolving Phase Ambiguity

Phase ambiguity can be resolved with a characteristic response curve that utilizes both positive and negative slopes to distinguish these operating points. The Phase Corrector makes use of this information in selecting one of these points as the correct operating position. Such a response curve is illustrated in Figure 2(b). This curve can be implemented by using a bi-directional counter in place of a uni-directional forward counter. The sign of the number accumulated in such a counter is considered either positive or negative depending upon whether the net count represents an excess of either forward or reverse counts. To produce the response curve shown in Figure 2(b), reversing control signals, derived from the corrected bit timing of Figure 2(c), are applied to the bi-directional counter in the fixed time relationship as indicated by Figure 2(d). The points and direction of the reversing signals correspond to the points on curve 2(b) where the slope changes.

Here again, the in-phase position of the corrected bit timing will yield 128 counts [as represented by Line Signal 2(e), Line Signal 2(f) requires further explanation] but also the total counts in two intervals will have resulted in as many forward counts as reverse counts, thus producing

a net count of zero. When the corrector is out of phase with the line signals, the accumulated counts over two successive count intervals will be represented by a number greater or less than zero. A number greater than zero results from an excess of forward counts whereas a number less than zero results from excess reverse counts. Hence, the sign of the number can be used directly to indicate the direction of error. The incremental correction that is applied as a result will be in a direction to reduce the algebraic count. On succeeding measurements, the subsequent corrections will ultimately reduce the count to zero and optimum sampling will result. By testing the response curve of Figure 2(b), it will be recognized as before that there are two phase positions that will yield zero counts in the error counter. It should also be recognized that once the direction of correction has been assigned to the signs of the number in the error counter it remains fixed. If a positive number is selected to subtract counts from the bit timer thereby retarding the bit timing phase, a negative number will always add counts to advance the phase. If it is assumed that an advanced phase in the bit timing is represented by a slight displacement of the line signal to the right from that shown in Figure 2(e), it appears that a positive number will result from the line transitions intersecting curve 2(b). If the line signal is now displaced an additional half bit to the right, it will be seen that the error count will now indicate a negative number. Since the bit timing phase was advanced in both cases only the positive numbers produce retard corrections to counter the phase error. The negative error counts only cause additional advancing thereby accelerating the phase displacement until counter corrections are produced. Hence, only one of the zero error count positions will result in a stable operating condition, being uniquely defined by slope of the characteristic response curve.

Optimum Phase Resolution

There is an additional advantage gained by using the bi-directional counter. Since the count interval, as defined, is the time period between a line transition and the corrected timing probe signal, point P Figure 2(c), a count interval can extend up to the period of one bit time under certain phase conditions. When accompanied with a biased line condition, it is possible for a line transition to occur during the count interval of the previous line transition. This will result in the second transition not being accounted for and cause an erroneous correction. Examining Figures 2(c) and 2(d), it can be seen that there will be an equal number of forward counts and reverse counts in any interval between the probe signal, P, and the following timing signal reversal, point S. Since an equal number of counts in both directions does not change the number in a bi-directional counter, the count interval can be terminated on either the positive transition, S, or negative transition, P, of the corrected bit timing and yield the same total error count. With count interval stops occurring every half bit, an interval can never exceed a half bit period as shown in Figure 2(f). This will insure that every line transition is accounted for on line signals having up to 50 percent bias and distortion. Figure 2(f) shows in phase line signals with 25 percent marking bias. The effect of this feature is to provide correct error indications for all phase positions, thereby giving the corrector the capability of overcoming phase drifts up to one half bit resulting from line interruptions.

Functional Diagram

A functional diagram of an optimum Digital Phase Corrector is shown in Figure 3. Clock pulses for the corrector, derived from the fixed timing source, are coupled to a seven stage Bit Timing Chain through the add-subtract correction logic. The Bit Timing Chain provides corrected square wave bit timing signals with transitions in the center of the received data bits. In addition, it provides the stop pulses every half bit time for the Count Period Bi-Stable to terminate the count intervals and provides timing to the Direction Control Bi-Stable which determines the direction of count in the Bi Di-

rectional Counter when it is counting. The command for a correction is applied to the add-subtract logic at the end of the second count interval which is determined by gating the line signal with the Count Period Bi-Stable. A marking line, in conjunction with the Count Period Bi-Stable when reset by a stop pulse, will trigger the correction logic at end of the interval started on a space-to-mark line transition. The state of the last bi-stable in the Bi-Directional Counter directly indicates the sign of the number that determines whether a clock pulse is added or subtracted from the Bit Timer on the correction command. On the completion of a correction, the add-subtract logic resets the Bi-Directional Counter to zero thus preparing it for the next error measurement.

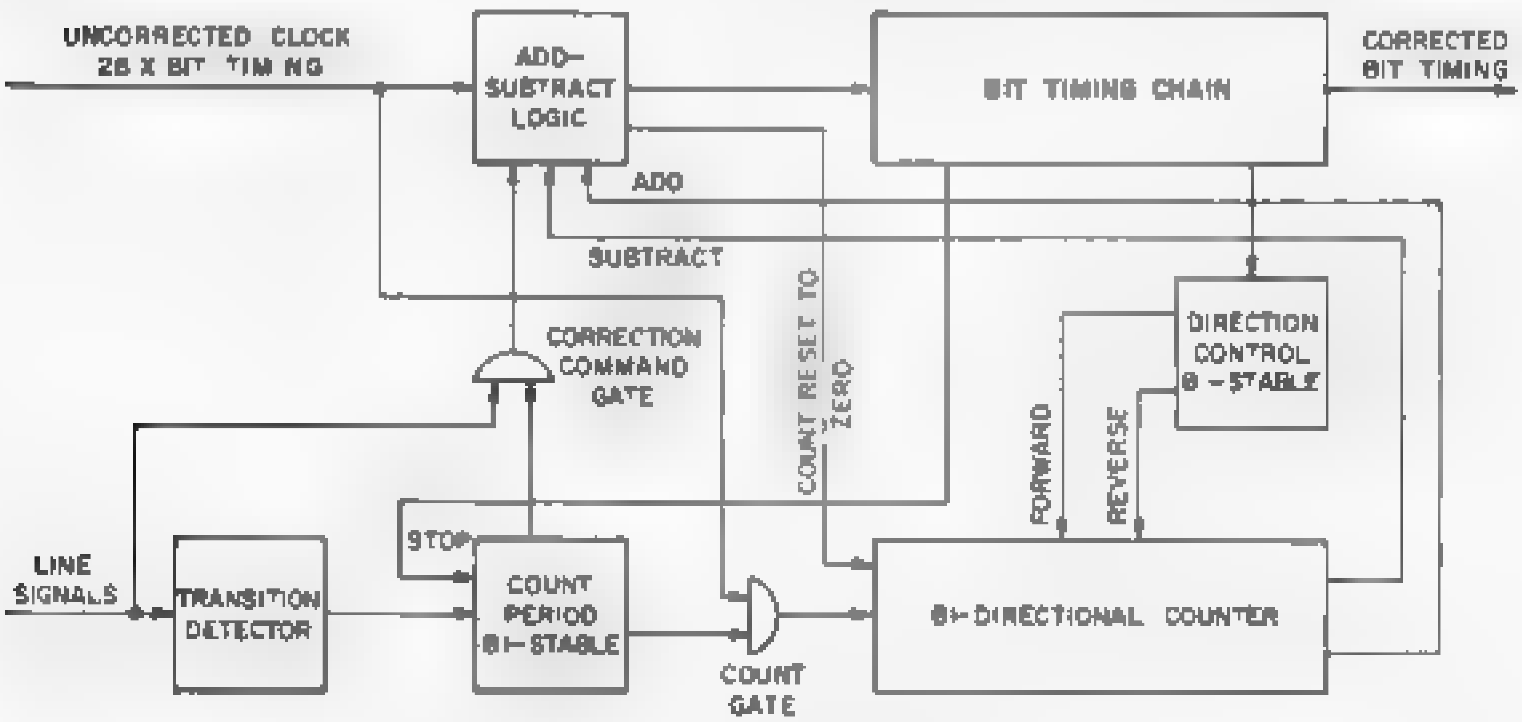


Figure 2. Block Diagram for Optimum Phase Corrector

Zero count is defined as the reset state of the Bi-Directional Counter. It is also interpreted as the lowest positive number and is not recognized uniquely as a no-correction signal. This is due to the fact that the error indication is derived directly from the last stage of the Bi-Directional Counter which provides only the sign of the number or direction of error. To recognize zero uniquely as a condition of no correction requires additional logic which contributes nothing to the effectiveness of the Phase Corrector. The only consequence of making a correction on zero is to introduce a nominal jitter in the timing signal equal to one correction increment. That is, a correction made on zero, which is the lowest positive number, will change the phase to cause the next error to be the lowest negative number, and so forth. Hence, the correction alternates between advances and retards when the corrector is locked in phase introducing an insignificant jitter of less than one percent of the bit timing signal.

Conclusion

The Timing Phase Corrector used in the Comlognet System is based on the fundamental principles of optimum phase correction on serial random bit stream as defined in this article. It is one of the simplest digital phase correctors of this type. The rate of correction is a function of line transition rate but is independent of the magnitude of phase error, which gives it a rapid response characteristic. This is a desirable feature in the Comlognet Circuit Switch application whereby synchronized communication links are circuit switched to other links to form a tandem connection. In this mode of operation, a phase adjustment is required between links each time a connection is established. This is accomplished by providing a phase corrector in the send leg as

well as the receive leg of circuit switch links. The send phase corrector in this case samples its own line. When a link is circuit switched to another link, the relaying send leg will be connected to the receive leg of the preceding link. In this event, the send timing of the relaying link slaves to that of the receive line of the preceding link which, in turn, is a slave to its originating send station's timing.

When circuit switch connections are made, the phase adjustment between links is accomplished rapidly and without loss of synchronism on the individual links to insure immediate service for the circuit switching subscribers.

In applications where noisy communications are used such as radio circuits, a phase corrector with a fast response characteristic may be a disadvantage. In such cases corrections made on noise signal may introduce a large amount of jitter in the timing signal. To resolve this problem, a phase corrector should have a relatively slow response or be designed to effectively discriminate between correct signals transitions and noise signals. Various forms of digital integrators may be added to the basic phase corrector design to resolve this problem. As an example, an integrator can be made to effect correction when a set number of error indications of the same direction occur in succession. Another type effects a correction when a net error indication in a given direction exceeds a given threshhold. Effective noise integration can also be obtained by using proportional correction, that is taking into account magnitude of error in determining rate of correction.

MR. E. J. CHOJNOWSKI has been assigned to the Comlognet Program for the past two years. He is responsible for adapting Government furnished cryptographic equipment to the Comlognet system and for the development of the system's Transmission Timing Facility. Mr. Chojnowski also contributed to the development and planning of various special test and monitoring equipment associated with the Comlognet Technical Control Facility.

He was one of the major designers, under the Switching Development Engineer, in the development of electronic cross-office circuitry for Plan 55. He supervised electronic applications in the development of Plan 57. He has extensive design experience in semi-conductors and vacuum tube circuitry for switching applications.

Mr. Chojnowski received his B.S. degree in Electrical Engineering from Northeastern University in 1952 prior to his employ with Western Union.

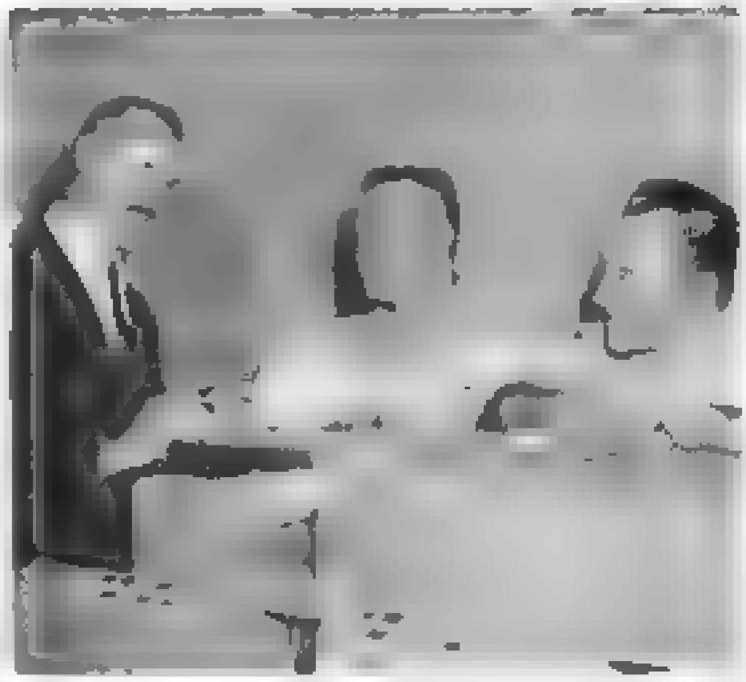
He has several patents on Phase Correctors and Switching Systems.

Philip R. Easterlin, Planning Engineer, Plant & Systems

WESTERN UNION TESTS VIA TELSTAR

A Summary

Western Union has recently completed a series of experimental international and domestic test demonstrations of various record communications via the "Telstar" satellite. The tests were conducted through arrangements made with A.T.&T. (American Telephone and Telegraph Company) and in cooperation with the BPO (British Post Office) and the French P&T (Posts and Telegraphs) administrations. The tests consisted of Telex, Private Wire, Data, and Facsimile transmissions. As was generally expected, Telstar provided a transmission path comparable to that of a microwave relay tower and the overall results from a transmission standpoint were completely satisfactory during the limited time period of the scheduled passes.



Western Union test data being transmitted from Norton Air Force Base, in California to TELSTAR and returned to the compound terminal in 53 seconds

During the test period, which began August 20th and extended through September 7th, Western Union was interconnected at New York to VF (voice frequency) bands provided by A.T.&T., which in turn were routed over landline facilities to their satellite radio station at Andover, Maine. From Andover, the overseas transmissions were via Telstar to satellite radio stations at Pleumeur-Bodou, France, and to Goonhilly Downs in England. From these stations the circuits were extended via landline facilities into Paris and London, respectively.

The test schedule provided two, and in some cases three, Telstar passes daily. Nine of the test periods were for international passes to either France or England. The remaining passes were used for domestic transmissions in which case the circuits from New York to Telstar and back to New York were used in conjunction with landline facilities for test demonstrations between different cities in the U. S. The transmission period varied for each Telstar pass and ranged from 17 to 48 minutes. However, this was shortened somewhat as A.T.&T. used several minutes of this time for tuning and also for telemetry control signals which cut the batteries in Telstar on and off for each pass. On one occasion, the exception throughout the series of tests, an atmospheric storm over the Andover radio station seriously interfered with telemetry control and transmission through the satellite.

Western Union was allocated two VF bands through Telstar for international passes and three VF bands for domestic passes. One VF band was conditioned, or equalized for delay distortion, and this was used for the Data and Facsimile transmissions. The other two VF circuits were of normal voice quality. One of these was connected to a narrow band carrier channel terminal which provided a number of DC telegraph channels for Telex, Private Wire, and regular message cir-

cuits. The third VF band was used for engineering measurements.

Following is a brief outline of typical test demonstrations conducted for various services:

Telex

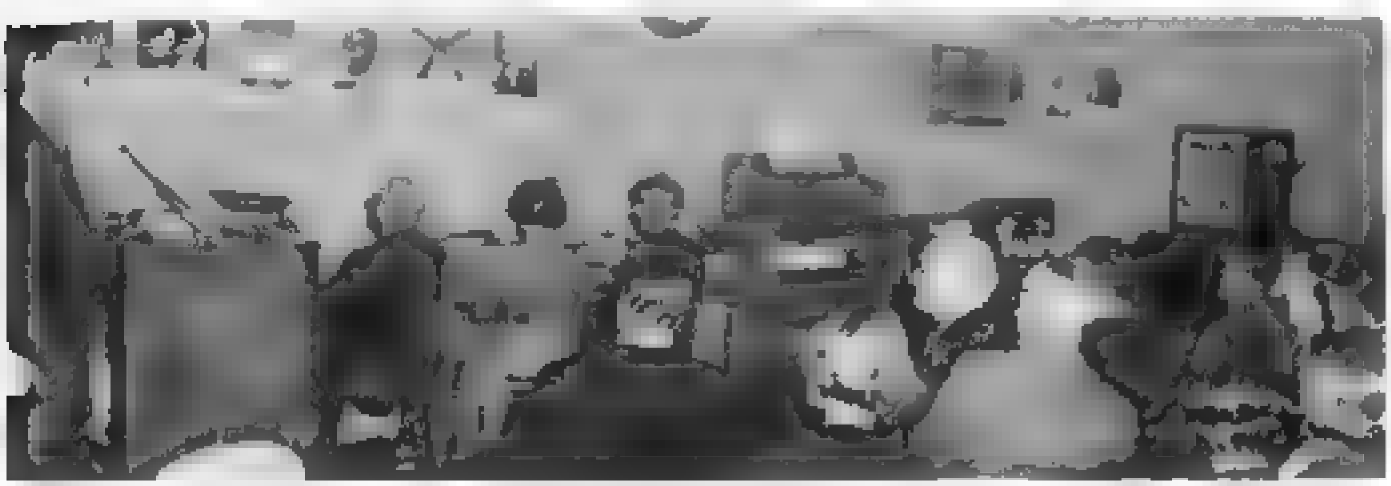
The New York Telex Exchange was connected to Telstar via three trunk circuits. These were arranged, on international passes, to provide fully automatic direct-dial Telex connections between Western Union's domestic network and the BPO or French P&T Telex network. On domestic passes, the trunk circuits were looped through Telstar and back to the New York Telex Exchange; thus by dialing a special prefix, Telex connections between two points in the domestic network were routed via Telstar.

Data And Facsimile Tests

Because of insufficient time to provide the required terminating equipment at overseas points, all data and facsimile transmissions on international passes were made on a "bust-back" basis, i.e., New York—Telstar—France or England—and back to New York. The data transmission tests involved the use of two Digitronics paper tape terminals, equipped with error detection and operated at 1000 WPM (words per minute). A data test, using a compound terminal, was also made from the Air Force Datacom Center at Norton Air Force Base in California, via Telstar to England and return. Transmission performance on these tests was within the acceptable operating range, equivalent to that experienced over domestic landline facilities.

Two types of Western Union facsimile machines were used in the Telstar tests, Weatherfax and Letterfax. A leak circuit was taken from the Weatherfax network to two machines, the first of which provided local copy directly from the circuit and the second machine copied the same transmission routed via Telstar to France and back to New York. With the exception of the transmission delay of approximately 100 ms (milli-seconds), there was no appreciable resolution loss as a result of the extended transmission path.

The Letterfax transmission to overseas points and return was equally satisfactory. Letterfax transmissions were also routed via Telstar on domestic passes and then over Western Union's Wirefax network to other cities in the U. S.



MR. PHILIP R. EASTERLIN was Coordinator of the Western Union Tests via Telstar and responsible for arrangements between A.T.&T. and various departments of Western Union. He has been responsible for the overall planning of Western Union's U. S. TELEX network and has represented the Company on numerous overseas assignments including the CCITT Telecommunications Conference in New Delhi, India and Geneva, Switzerland.

Mr. Easterlin officiated at the press conference shown above during one of the tests via TELSTAR.

J. M. Reardon, Senior Engineer, Plant Department

Microwave Radio Beam System*

It is not the intent of this article to discuss the general subject of microwave development at length but to limit it to the consideration of the special problems that Western Union had to solve in preparing the new transcontinental microwave system for operation.

Prior to the initiation of the present Western Union microwave construction, a great deal of time was spent studying a microwave grid network covering the United States as shown in Figure 1. This study resulted in a large number of system concepts. Three keypoints upon which the systems hinge were:

a. The trunk route should employ avoidance routing,
b. Each route should make efficient use of available RF channel spectrum,
c. The system should be designed for data transmission.

Avoidance Routing-Junction Stations

Avoidance routing dictates that trunk systems must avoid population centers and critical target areas by at least 30 miles. In practice the distance is more like 50 to 75 miles. Since the points which have been avoided originate and receive message traffic they have to be served. To meet this need, junction stations have been established on the trunk route where the radio is demodulated to base band and broken into frequency blocks. Message traffic destined for the terminal is fed into a tributary system operating between the junction station and the terminal within the target area. If for any reason the terminal ceases to operate, the trunk route is not affected.

To avoid dependance on existing operating personnel within the cities, it was necessary to man some of the junction stations. Investigation of the system operating procedures indicated that there were two types of junction stations, major and minor. A major junction station is the intersection of three or more trunk routes as shown in Figure 2. A minor junction station is the point where a trunk route is split by the interconnection of a tributary or a spur system serving either a city or customer location. Since a major junction station has the ability to select more than one alternate route, these are the points that should be manned on a 24-hour-per-day, per week basis.

A junction station also becomes a new pick-up point for message service for business moving out of the cities into suburban areas. Now, rather than extend facilities or, in many cases, rebuild facilities to accommodate band widths greater than voice or telegraph channel requirements, direct contact can be established between the place of business and the junction station.

Fault Alarm Systems

The present system under construction requires six major junction stations. Although limited in number these points are supplied with all of the necessary information to monitor and control the network. In fact the fault equipment is so arranged that any one station could be set up to monitor and control portions of the entire network.

Since the message service is 4-wire, a route is not unworkable if only one direction of service is lost. If you transmit from New York to St. Louis, via Chicago, and receive via Cincinnati, service continuity is maintained between the using terminals. Therefore, it was necessary that any unattended station transmit its fault information in both directions, although only one major junction station normally monitors and makes decisions for a route. This does away with the necessity of a two-way radio path required in an interrogation type fault system. In the other direction the fault information is transmitted to another major junction station or supplemental

* This article has been condensed from a paper presented at the 16th Annual Convention of the Armed Forces Communications and Electronics Association in Washington, D. C. on June 12, 1962. Complete text of this presentation has been published in the August, 1962 issue of SIGNAL, official journal of the AFCEA.

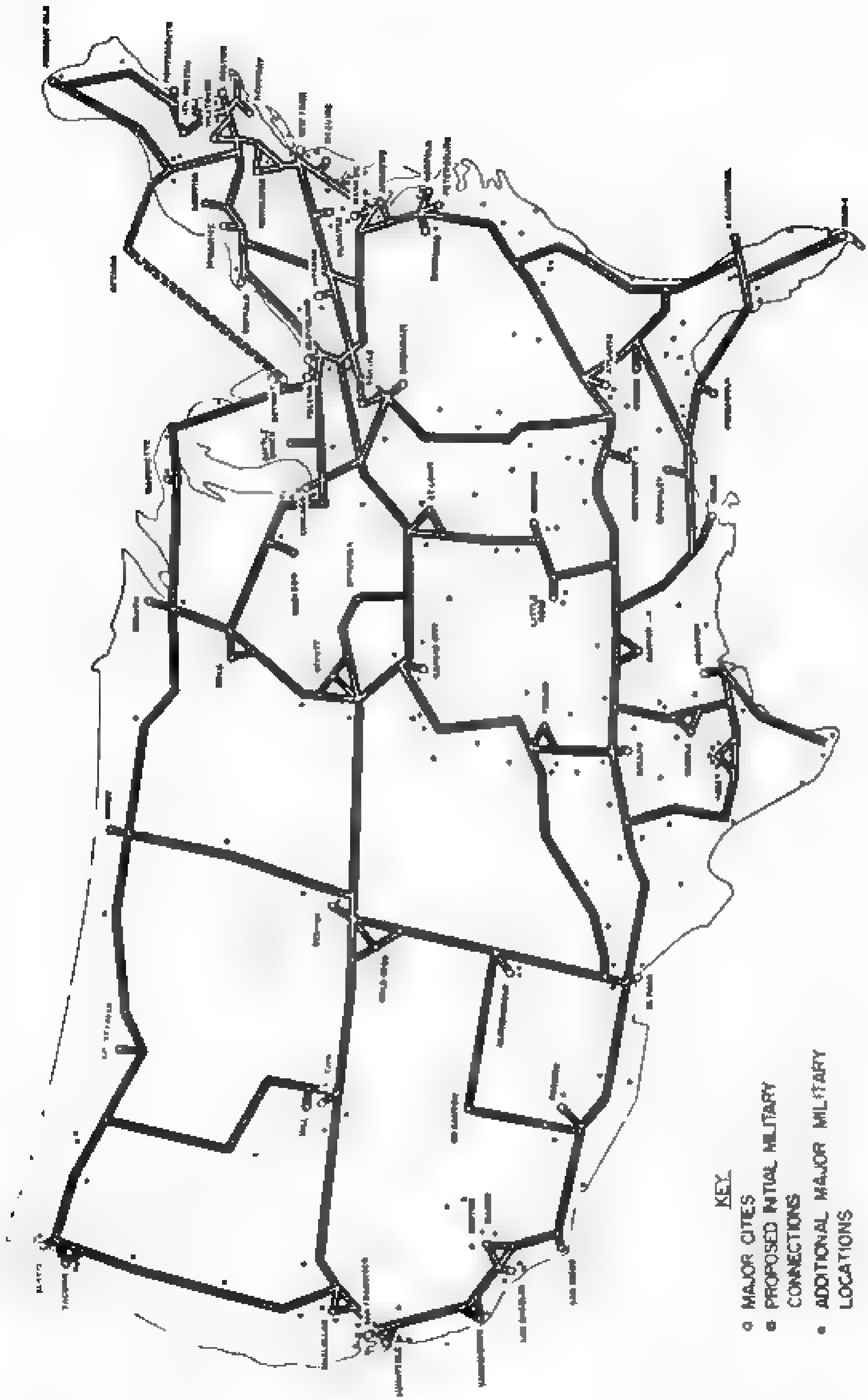


Figure 1. Proposed Western Union Grid for Microwave Radio Beam System

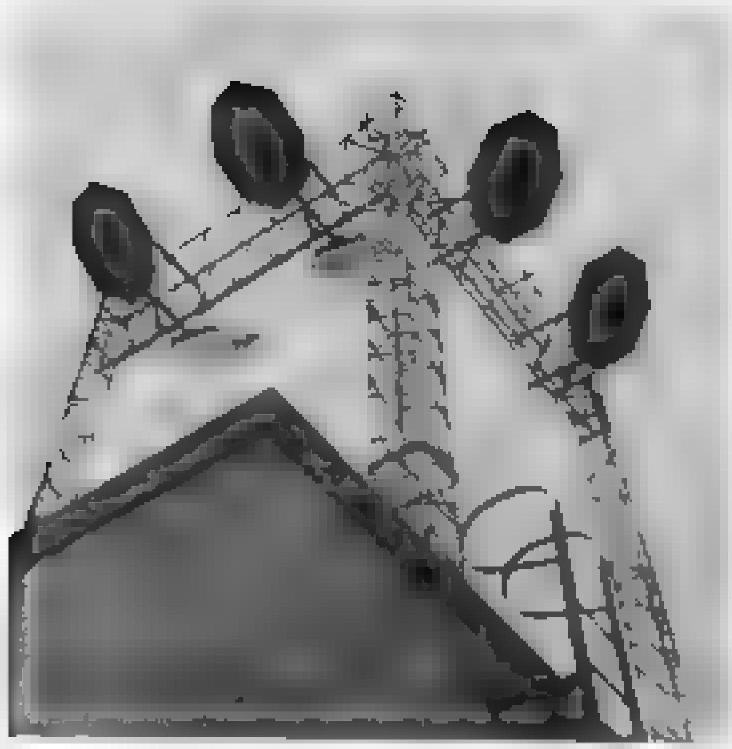


Figure 2. Junction Station Showing Three-Directional Antenna

monitoring point, which serves as an alternate point of inspection and control. All routes have an alternate monitoring point, which is activated if the normal station either needs assistance in diagnosing trouble or for some reason should cease to operate. In addition to monitoring the system major junction stations can control certain switching functions at minor junction stations and unattended terminal locations.

At each major junction station there is a carrier multiplex fault alarm system which operates independently of the carrier multiplex equipment in that station. The system monitors every pregroup (group of four voice channels) as it is received and transmitted at the output or input to the radio equipment. With the aid of a routing directory and the exclusive phone line between major junction stations troubles can be pinpointed in short order. If the carrier multiplex fault alarm system does nothing else it should eliminate the familiar statement, "Everything is okay here; the trouble must be at your end." Additional facilities available to personnel at a major junction station are: direct phone lines to the terminals under their control, and communications to their maintenance forces, either by radio service channel, or VHF radio installed in all radio maintainer vehicles.

Full RF Channel Occupancy

The object of full RF channel occupancy is to obtain full usage of all available channel assignments within the 3700-4200 and 5925-6425 megacycle common carrier bands without interfering with existing frequency assignments or blocking future system expansion of any common carrier presently in service. Also, the new system must be laid out to avoid self interference from "overshoots" and route interconnection at junction stations.

As a first step, information on existing common carrier systems was collected. Accurate information concerning beam azimuths, polarization, and the location of the receiving terminal for one-way video service, was difficult to obtain. Some information from using agencies and equipment manufacturers was available. As the information was compiled it was transferred to a set of maps covering Southern Canada, the entire United States and Northern Mexico. Information on each map included station locations, transmitting channel assignments, polarization, and antenna type. The same information was also cataloged in a computer. When a new path was investigated, data were fed into the computer, programmed to report back the distance between and the angle of discrimination to all interfering stations located within a prescribed arc, plus the antenna discrimination of the distant station.

Our investigation revealed that our principal competitor had the major portion of its facilities in the 4 KMC band while the 6 KMC band was occupied by short haul independent common carriers. In addition to describing our problems in coordinating with these systems, it is necessary to review the background information on the frequency allocations within the two bands.

4 KMC Common Carrier Band

The 3700 to 4200 megacycle common carrier band is divided into 25 channels, each with a 20 megacycle band width as shown in Table I. Western Union numbers the channels in consecutive order starting with number one at a center frequency of 3710 megacycles. Channel 25

with a center frequency of 4190 megacycles is not considered in any of the allocation plans, but may be employed in special instances. The remaining 24 channels are used in two basic allocation plans; one plan employing the twelve even numbered channels, the other the 12 odd numbered channels. Although the numbering system is different, the allocation is identical with the AT&T plan in terms of alternate system location and intermittent stages of growth.

As shown in Table I, AT&T has two channel assignment numbers for each frequency. One channel assignment designation code is constant within an AT&T Long Lines Area but may change to the other code in an adjacent area. To overcome the many channel groupings and designations used by AT&T as shown in Table II, as well as specifying the channel polarization, Western Union uses a letter code as shown in Table III. Table IV indicates the simplicity of the W. U designations versus the various AT&T designations for the same group of channels. As an example, if after coordination our records indicate that a transmitter is designated as "Q," the table indicates that the transmitter has "full occupancy in the 3700-4200 mc band" and can transmit WU channels 1, 5, 9, etc. with a vertical polarization and WU channels 2, 6, 10, etc. with a horizontal polarization. A designation of QH would mean that the transmitter was coordinated half occupancy and was confined to the use

Table I
Allocation of W. U. and AT&T Plans in the 3700-4200 megacycle band

FREQUENCY MC	WU NO	AT&T NO	AT&T NO
3710	1	7	7A
3730	2	1	1A
3750	3	7a	7B
3770	4	1a	1B
3790	5	8	8A
3810	6	2	2A
3830	7	8a	8B
3850	8	2a	2B
3870	9	9	9A
3890	10	3	3A
3910	11	9a	9B
3930	12	3a	3B
3950	13	10	10A
3970	14	4	4A
3990	15	10a	10B
4010	16	4a	4B
4030	17	11	11A
4050	18	5	5A
4070	19	11a	11B
4090	20	5a	5B
4110	21	12	12A
4130	22	6	6A
4150	23	12a	12B
4170	24	6a	6B
4190	25	13	13A

Table II
4KMC Channel Groupings

WU	WU	AT&T	AT&T	AT&T	AT&T	AT&T	AT&T
1	ODDS LOW	7	7A	SLOTS LOW	SA	SLOTS A	SLOTS B
5		8	8A				
9		9	9A				
13		10	10A				
17		11	11A				
21		12	12A				
25		13	13A				
3	ODDS HIGH	7a	7B	SLOTS HIGH	SB	SLOTS B	SLOTS A
7		8a	8B				
11		9a	9B				
15		10a	10B				
19		11a	11B				
23		12a	12B				
2	EVENS LOW	1	1A	REGULARS LOW	RA	REGULARS A	REGULARS B
6		2	2A				
10		3	3A				
14		4	4A				
18		5	5A				
22		6	6A				
4	EVENS HIGH	1a	1B	REGULARS HIGH	RB	REGULARS B	REGULARS A
8		2a	2B				
12		3a	3B				
16		4a	4B				
20		5a	5B				
24		6a	6B				

of WU channels 2, 6, 10, etc. with horizontal polarization. The letter code "R" covers the same channels as does "Q" but with reverse polarization. The letters "S" and "T" cover the other allocation plan available within the 3700-4200 Mc band.

Table III

Letter Code Used by Western Union for 4KMC Channel Polarization Allocation

LOW				HIGH			
Q		R		S		T	
V	H	V	H	V	H	V	H
1	2	2	1	3	4	4	3
5	6	6	5	7	8	8	7
9	10	10	9	11	12	12	11
13	14	14	13	15	16	16	15
17	18	18	17	19	20	20	19
21	22	22	21	23	24	24	23
25			25				

Either basic allocation plan uses its 12 frequencies to develop six 2-way systems by using each frequency twice at each repeater site, while the antennas provide the decoupling necessary to meet the performance specifications. Using either the odd or even channels the transmitters and receivers alternate with a 40 megacycle spacing at each station, so that the minimum separation between transmitters is 80 megacycles and the same minimum separation between receivers is obtained. In going through a station, a channel frequency shift of 40 megacycles is used with the received frequency alternating up and down at successive stations. All channels within a basic allocation require only a single polarization.

A 4 KMC route is considered having full occupancy when both odd and even channels are used. This is accomplished by each allocation having the opposite polarization which takes advantage of the high polarization discrimination of the antenna at the zero or "on beam" angle.

An important point, often overlooked in an initial discussion of calculating interference, is that a station does not interfere necessarily with every other station operating in the same frequency band. A transmitter does not interfere with another transmitter, it only interferes with a receiver. Also the requirement for interference into a receiver operating on an adjacent channel frequency is far less severe than that for co-channel operation. Therefore, before we could coordinate in the 4 KMC band we had to know what routes AT&T planned for interstitial operation and the frequency pattern the route had to use to meet internal coordination problems; i.e., a route could not be interstitial unless the frequency channel assignments selected coordinated with channels already in use on interconnecting routes. Without testing for minimum foreground reflections, it is difficult to designate a site where the same frequencies can be transmitted in one direction as are received in the opposite direction, in order to match up frequency assignments between two junction points.

Table IV

Designation of Groups of 4 KMC Channels Polarized

WU	AT&T
QV	7-13V; 7A-13AV, SAV, SLOTS LOW V
QH	1-6H; 1A-6AH, RAH, REGULARS LOW H
RV	1-6V; 1A-6AV; RAV, REGULARS LOW V
RH	7-13H, 7A-13AH, SAH SLOTS LOW H
SV	7a-12aV, 7B-12BV; SBV, SLOTS HIGH V
SH	1a-6aH, 1B-6BH; RBH; REGULARS HIGH H
TV	1a-6aV, 1B-6BV; RBV, REGULARS HIGH V
TH	7a-12aH; 7B-12BH, SBH, SLOTS HIGH H

6 KMC Common Carrier Band

Similar information was obtained on where AT&T planned to add channels in the 5925-6425 common carrier band to their existing 4 KMC routes. In the 6 KMC band, there are 16 channels, each with a band width of 30 megacycles shown in Table V. Unlike the 4 KMC band, transmitters at a station are in a block at one end of the band and all receivers at the station are in a block at the opposite end of the band. In going through a station, a channel frequency shift of 252 megacycles is used with the frequency blocks alternating as transmitter or receiver frequencies at successive stations. Adjacent channels within both

the transmitting and receiving blocks alternate in polarization. The basic allocation plan uses all frequencies to develop eight 2-way systems.

Table V

Allocation of W. U. and AT&T Plans in the 5925-6425 megacycle band

FREQUENCY MC	W U NO	AT&T NO	GT NO	CCIR NO
5925.5		10		
5937.8			1	
5945.20	11	11		1
5952.6			2	
5967.4			3	
5974.85	12	12		2
5982.3			4	
5997.1			5	
6004.50	13	13		3
6011.9			6	
6026.7			7	
6034.15	14	14		4
6041.6			8	
6056.4			9	
6063.80	15	15		5
6071.2			10	
6086.0			11	
6093.45	16	16		6
6100.9			12	
6115.7			13	
6123.10	17	17		7
6130.5			14	
6145.3			15	
6152.75	18	18		8
6160.2			16	
617[illegible].5		19		
6177.5		20		
6189.8			21	
6197.24	21	21		1
6204.7			22	
6219.5			23	
6226.89	22	22		2'
6234.3			24	
6249.1			25	
6256.54	23	23		3'
6264.0			26	
6278.8			27	
6286.19	24	24		4'
6293.6			28	
6308.4			29	
6315.84	25	25		5'
6323.3			30	
6338.1			31	
6345.49	26	26		6'
6352.9			32	
6367.7			33	
6375.14	27	27		7'
6382.6			34	
6397.4			35	
6404.79	28	28		8'
6412.2			[illegible]	
6424.5		29		

In the 6 KMC band both Western Union and AT&T use the same channel designations. The letter codes of A, B, C or D for the 6 KMC channel and polarization allocation is shown in Table VI and is used in the same manner as that previously described for the 4 KMC band.

Although this allocation plan is identical to the C.C.I.R. and TH stations in terms of ultimate system allocation, it is not and could not be consistent with many frequency plans used by some common carriers. A conscientious effort has been made to avoid these short haul systems although coordination would have been minimized greatly if these systems operated with compatible TH frequencies.

Table VI

Letter Code Used by W. U. and AT&T for 6KMC Channel Polarization Allocation

HIGH				LOW			
A		B		C		D	
V	H	V	H	V	H	V	H
28	27	27	28	18	17	17	18
26	25	25	26	16	15	15	16
24	23	23	24	14	13	13	14
22	21	21	22	12	11	11	12

Data Transmission Requirements

Data transmission places a requirement on a transmission facility that normally is more severe than that required for either voice or conventional video. The nature of speech is such that even if a short break occurs during a conversation it can be overlooked because it can be filled in by the listener. If the interruption is critical, the listener will recognize it and can ask for a repeat immediately.

Video circuits have other peculiarities when it comes to a tolerance of outages. Video transmission breaks of short duration usually show up on the home TV screen as a picture roll. If this occurs infrequently and if not preceded by long periods of picture noise, "snow," it will generally cause few complaints. Unfortunately normal data receivers do not have the redundancy of the human eye or ear.

Within the framework of data itself there is a considerable difference in tolerable interruptions. The speed of transmission is important since even a short break which might not produce an error in relatively low speed transmission can cause an error in higher speed data. To some extent, the degree of error detection

and correction designed into data systems reduces the demands placed on a transmission system. However, the reliability of an overall system is still in a large part determined by the continuity of the transmission facilities.

The minimum requirement for a Western Union microwave system handling data is to use two active radio systems over each route with both systems carrying identical information and employing spaced frequencies for transmission over each hop of the system. With the proper spacing the probability of atmospherics causing a simultaneous break in each transmission path is remote. In the design each system has separate transmission lines, antennas, and no-break emergency power units. The no-break power unit shown in Figure 3, insures that not a single telegraph pulse would be dropped if there is a commercial power failure. Each power unit is operated at 50 percent of capacity and in the event of failure of one machine the remaining machine is automatically switched to carry the entire power load at the station.

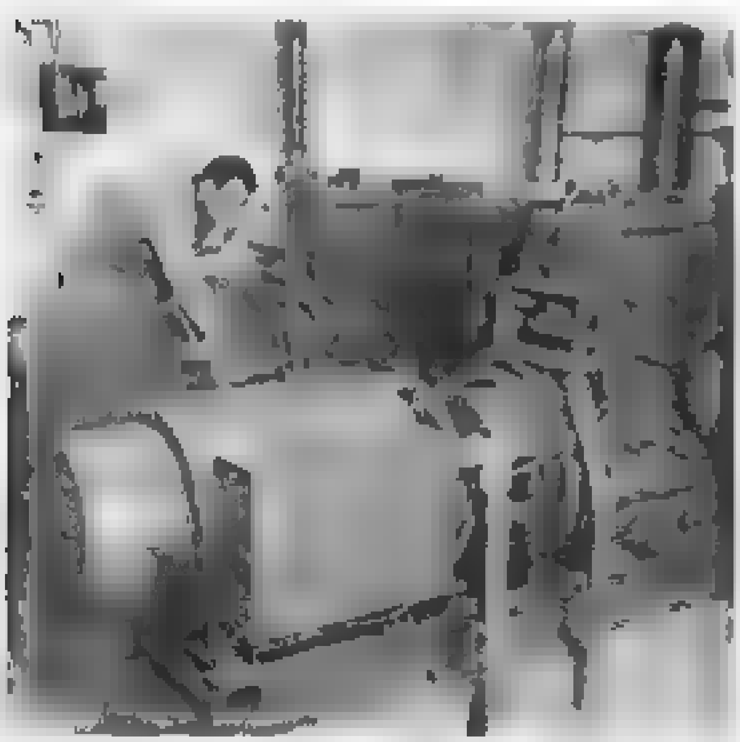


Figure 3. No-Break Power Unit

Combiner

The two systems are combined at junction stations which are separated on the average by 10 to 13 repeater stations. A combiner is an electronic device that chooses the best combination of the two systems, so that the signal-to-noise is at least as good as the best of the two paths and sometimes as much as 3 db better than either path. A combiner makes use of the fact that when a radio system with automatic gain control starts to fail, the output signal at succeeding stations remains constant while the system noise increases.

The procedure for the operation of the combiner is as follows:

The message portion from each receiving terminal is fed into the combiner input. Within the unit the signals are combined in solid state devices with parallel operation of transistors to minimize circuit failure. Each circuit is monitored by the noise obtained from an out-of-signal slot from its respective system. If the noise in one of the systems increases because of fading or equipment degradation, the contribution of that circuit to the combined output is decreased while the other circuit is correspondingly increased.

In the event of a receiver failure at the terminal, the noise of the failed circuit would fall below that of the operative circuit, which has accumulated the noise from each repeater back to the send terminal. This particular form of failure is remote but it is protected against by monitoring a pilot frequency on each circuit. If this pilot is lost, the combiner switches to the other circuit.

The two pilots are combined and the output is automatically monitored to recognize a combiner failure. While this type of failure also is remote, because of component redundancy in the combiner, a bypass panel is employed to remove the combiner from the system upon loss of the combined output pilot.

There are two outputs from the combiner so that two systems carry on from that terminal.

IF Switching

A failure at any relay station would disrupt transmission between that point and the succeeding receiving terminal. After this failure there would no longer be a diversity system and any failure in the paralleling facility would result in complete loss of transmission between termin-

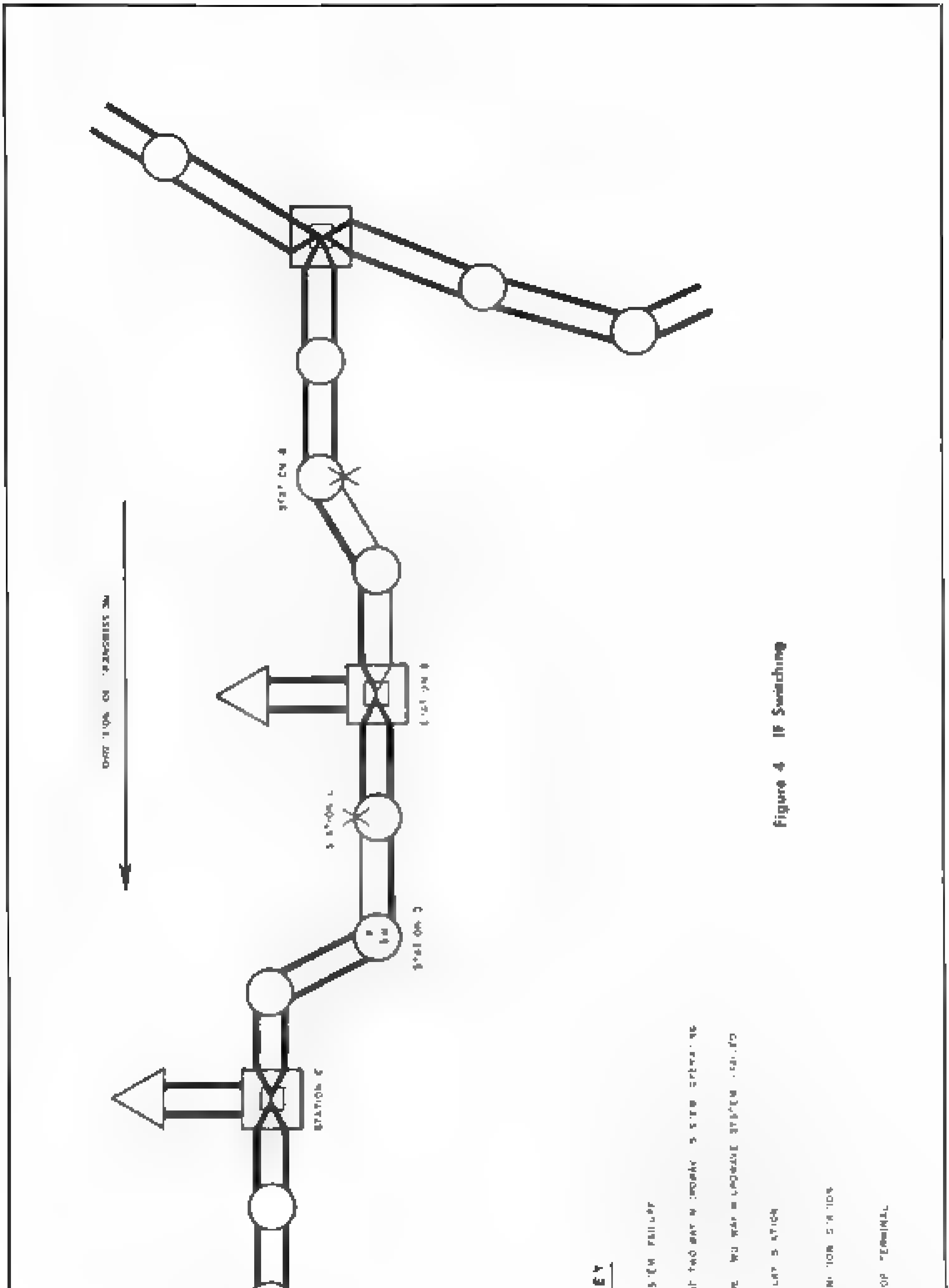


Figure 4 IF Switching

als. To minimize the effects of such equipment failure, we employ IF switching at every repeater station. In the event of a failure the transmitter associated with the failed half of the diversity system is bridged across the intermediate frequency receiver output of the operating system at the first station beyond the failure. This provides diversity operation beyond the affected unit and insures against additional equipment or propagation failures

An example of IF switching is shown in Figure 4. When a failure occurs at Station A, on a route not equipped with IF switching, the two active systems are not available until after combining at junction station B.

With IF switching, if a transmitter failed at Station C, diversity operation would be re-established at Station D rather than at the next combining point, Junction Station E

Multiplex Equipment

To meet the demands of data for variable inputs, the transistorized multiplex equipment has been assembled to give us easy access to standard blocks of frequencies as shown in Figure 5. In addition to telegraph and voice channels we have available band widths of 16-, 48- and 240 KC. Where necessary, external units are used to adjust any difference in frequency range, level and impedance between multiplex and data modem. Although we have some standard external "black boxes," additional units can be developed to meet customer's needs.

Present day limitations to data and facsimile transmission within a 4 KC channel are the number of voice frequency interconnections necessary to obtain a circuit between two using terminals. As the Western Union system goes into service there will be no voice frequency patches. Channel terminal units will appear only at the using terminals. To accomplish this there is the flexibility of patching 16 KC frequency blocks without the expense and disadvantages of an additional stage of modulation at every terminal. This is possible by directly modulating voice channels into a group frequency assignment of 12 channels at terminal stations as shown in Figure 5. At junction stations, which serve as message bundling points, pregroup modem racks are available to permit, when necessary, the demodulation of 12 voice channel groups into patchable frequency blocks containing 4 voice channels.

Conclusion

In conclusion, it may be stated that:

- In the years since the "Grid" was conceived there have been many requests for new data service. Not one of these requests required a redesign of the system.
- New spur systems are being extended from junction stations to meet customer requirements.
- Plans are now under active consideration to add broadband and Telex switching centers at junction stations. These centers will be important Western Union offices of the future.

Mr John M. Reardon has participated actively in the Micro Beam Expansion Program since the early planning stages

Upon graduation from the Virginia Military Institute in 1948 with a B.S. degree in Electrical Engineering, Mr Reardon joined the Plant and Engineering Department as an Engineer assigned to the Transmission Engineer In this capacity he worked on the initial installation and operational phases of the New York Washington Pittsburgh system. He was recalled to active duty during the Korean conflict and served as a Post Signal Officer. He then took an active part in the route layout of the Pittsburgh-Cincinnati-Chicago MLD-4A System and had an important part in the carrier multiplex engineering

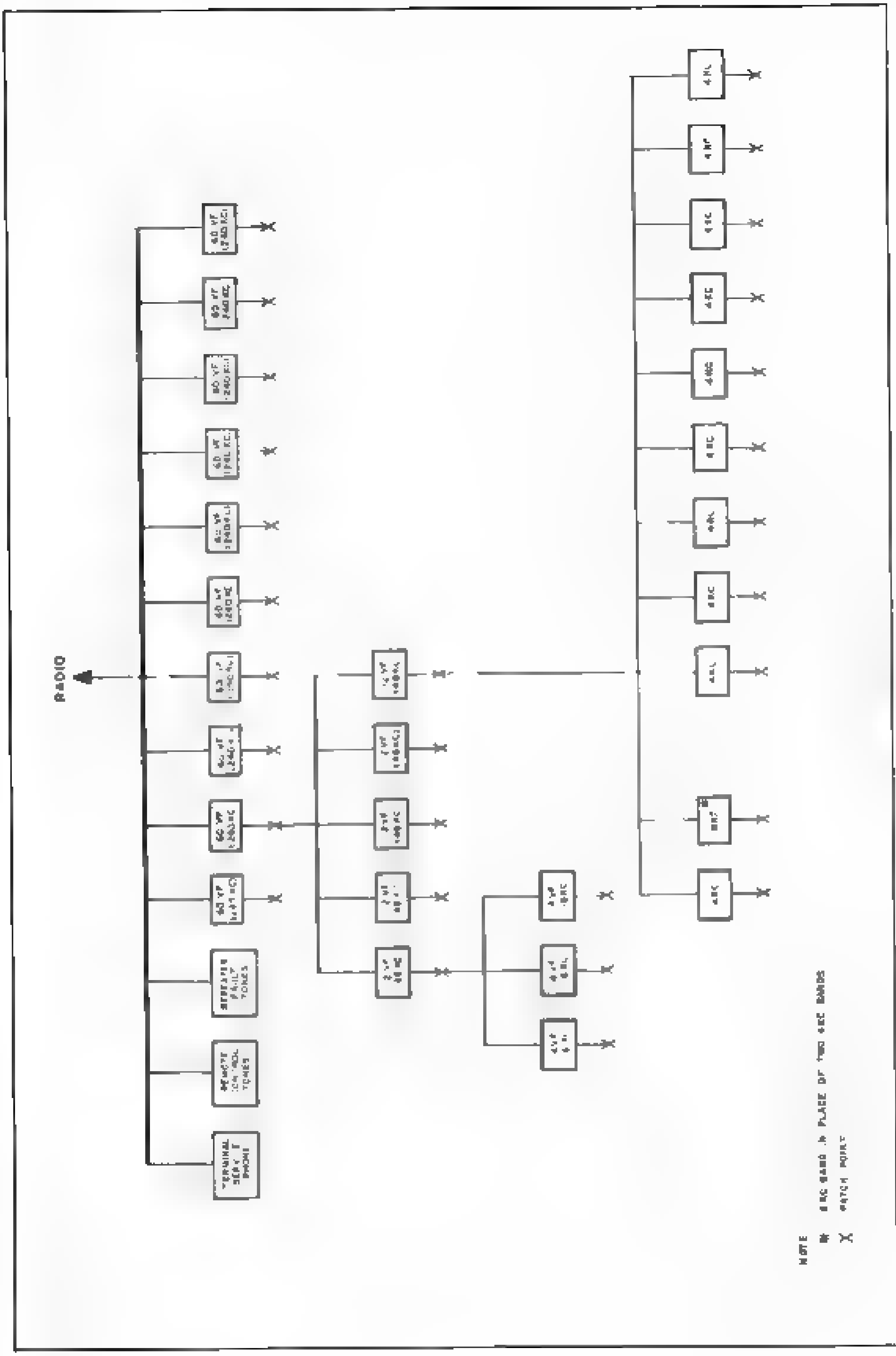
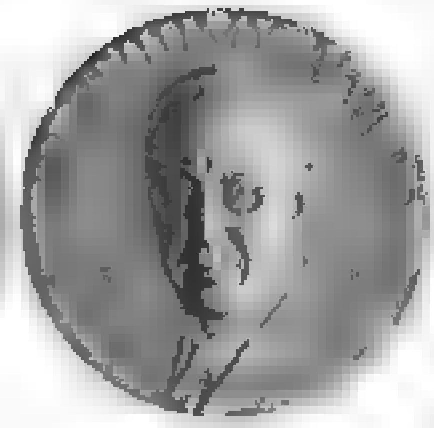


Figure 5. Multiplex Equipment Inputs

W. D. BUCKINGHAM—THE 1962 D'HUMY MEDALIST

The F. E. d'Humy Award for 1962 was presented to Mr. W. D. Buckingham on September 26, 1962 by the President of Western Union, Mr. Walter P. Marshall Mr. Buckingham is Assistant Electronics Engineer in the Research and Engineering Laboratories at Water Mill, N. Y

Mr. C. M. Brown, Vice President of Research and Engineering, presided at the ceremonies surrounding the presentation. He paid tribute to Mr. Buckingham for his unique contribution to the communications technology and emphasized the number of patents credited to his name. Mr. Buckingham has 34 issued patents and several pending applications. Mr Brown introduced the previous medalists, Mr. Robert Steeneck, Mr. Garvice H. Riddings, Mr. Harold F Wilder, Mr. W. Dail Cannon, Mr. J. Edwin Boughtwood, and Mr. F. Beaumont Bramhall

Mr. Marshall then presented the Award to Mr. Buckingham and stressed the importance of his development of the sensor for the Bomb Alarm System. This is not only important to Western Union but also to our National Defense.

Mr. Buckingham is the eighth recipient of the F. E. d'Humy Award. It includes a bronze medallion, an engrossed citation certificate, a gold lapel pin, and a $500 honorarium. The Western Union Telegraph Company established the award in commemoration of the leadership of Fernand E. d'Humy, who was Vice President of Development and Research before his retirement. Following his death in December 1955 this award has been given in his honor to a Western Union engineering, research, or scientific technical employee who has made a significant contribution to the telegraph art

The citation this year is given to Mr Buckingham "for his original ideas, fruitful research and inventions in many areas of communications and national defense." He joined Western Union in 1926 as an engineering apprentice and in 1927 was made a member of the staff at the Company's Electronics Laboratories at Water Mill, N. Y.

He had a major role in developing the sensor for the nationwide nuclear bomb alarm system provided by Western Union for the U.S. Air Force. He received the Franklin Institute Medal for his development of the Concentrated-Arc Lamp. He designed the optical system for a flat-bed facsimile scanner, the military plane boresighter, the optiphone voice communication on light beam, the depthometer used in connection with ocean cable plowing, and new cable balancing techniques. He made substantial contributions to the night fighter trainers and radar trainers developed for the Navy during World War II. He developed character recognition equipment that has important potential for future use.

Mr. Buckingham is a graduate of Case Institute of Technology where he received his degree in Electrical Engineering. He is the author of numerous technical papers and is a member of the IRE.

Patents Recently Issued to Western Union

System for Detecting Errors in Telegraph Transmission

D. J. Walker, R. H. Leonard

3,038,961—June 12, 1962

An improvement on the error detection methods of Patents Nos. 2,978,541 and 2,993,956 to provide protection against multiple errors. The 8-stage counter of the former patents has a modulus of 256 and since it will recycle upon a count of 256 it will fail to respond to losses of 16 or 32 pulses, or multiples thereof, occurring in certain levels. Faulty transmitters may cause such error patterns. By designing the counter for a modulus of 255 which is not a multiple of the assigned weight of any code level, a succession of errors less than 255 will not recycle the counter. Hence, so long as the block of information is less than 255 characters the counter cannot be recycled by a succession of errors in any one code level.

Line Feed Detector

A. A. Ortiz

3,038,962—June 12, 1962

An arrangement for indicating to a sending station if the receiving printer is properly feeding paper at the beginning of a message. A hinged assembly bearing a needle-like point drops upon receipt of a first combination of code characters so that the point is wedged into the paper against the platen, at the same time actuating a microswitch. Paper movement following receipt of a line feed will then allow the point to disengage to thereby close the switch whereby a signal is sent to the transmitter signifying proper operation of the line feed. The hinged assembly is released by an actuating member of a stunt box included in the printer and responding, for example, to the characters "W," Space, and the switch position may be transmitted to the terminal of a multi-party line as a function of the usual way-station selector.

Copy Marker in Facsimile Apparatus

D. M. Zabriskie

3,039,104—June 12, 1962

A device for automatically marking facsimile copy in the course of scanning or recording for such purposes as indicating that the copy has been transmitted, or for identifying the machine used. As shown, a scanner or recorder of the type which automatically rolls a card or sheet on a drum, which then moves axially but without rotation during scanning, is provided with a mechanism embodying a marker blade bearing on its projecting end a number of teeth spaced in a designated pattern. Wrapping of a copy sheet on the drum causes a first perforation in the copy while unwrapping at the end of the scanning operation completes the perforation according to the tooth pattern.

Photoelectric Balanced Modulator

G. B. Worthen, C. Jelinek

3,048,702—August 7, 1962

A balanced modulator, particularly for facsimile purposes, in which a photocell of double balanced anode construction is disposed within a magnetic field having a direction transverse to the electron stream. The magnetic field is excited by a carrier frequency so that variations in the photocell cathode emission caused by light excitation produce a signal modulated, suppressed carrier, output in a balanced circuit connected to the three terminals of the photocell. Shielding means for the photocell are provided and a biased construction for the assembly is suggested, if desired, for the purpose of neutralizing any d.c. component in the carrier circuit as would occur if the exciting magnet was directly connected to a vacuum tube or transistor oscillator.

Management Technique
Programming
Data Processing

Adamkiewicz, E. R. and Marra, A. J.: PERT—A Management Tool

Western Union TECHNICAL REVIEW, VOL. 16, No. 4 (Oct. 1962), pp 146 to 153

The article describes PERT (Program Evaluation and Review Technique) as it is applied at Western Union. Special emphasis is placed on the development of new programming techniques enabling the IBM 650 computer to be used in large scale PERT networks.

Examples of actual PERT networks are included.

Subscriber Set
Data Switching
Voice and Voice Record Service
In-Band Signaling

Stotz, R. P.: Point to Point Subscriber Set

Western Union TECHNICAL REVIEW, VOL. 16, No. 4 (Oct. 1962), pp 154 to 157

A special telephone terminal set was developed to implement the private-wire service interconnections associated with Western Union's Voice and Voice Record Service. The physical description, circuit layout, and operation of this unit are included in this article.

It is expected that such equipment will have an even wider application when the broadband line facilities become available.

Ocean Cable
Multiplex Telegraph Cable Transmission
Multiplex-Electro-Mechanical

Dickey, A. W.: Two-Channel Multiplex for Italcable Company

Western Union TECHNICAL REVIEW, VOL. 16, No. 4 (Oct. 1962), pp 158 to 159

This article briefly describes a two-channel printing telegraph system, with selective switching, recently installed for Italcable Company's Horta-Malaga-Rome cable.

Phase Corrector
Data Communications
Synchronous Transmission

Chojnowski, E. J.: Digital Phase Corrector

Western Union TECHNICAL REVIEW, VOL. 16, No. 4 (Oct. 1962), pp 160 to 167

In Western Union's recent development of the Air Force DATACOM —Phase I Comlognet system, a bit serial synchronous transmission scheme was adopted; to provide efficient high-speed data communication. This article describes a digital-type Phase Corrector which provides the basic means for synchronous remote data terminals in this system.

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TELSTAR
Transmission Tests

Easterlin, Philip R.: Western Union Tests Via *TELSTAR*

Western Union TECHNICAL REVIEW, VOL. 16, No. 4 (Oct. 1962), pp 168 to 169

This is a press release concerning the experimental test demonstration of various record communications via the TELSTAR satellite.

Tests consisted of TELEX, Private Wire, Data and Facsimile transmission.

Microwave Planning
Data Transmission
RF Frequency Coordination

Reardon, J. M.: Microwave Radio Beam System

Western Union TECHNICAL REVIEW, VOL. 16, No. 4 (Oct. 1962), pp 170 to 179

This article reviews the special problems solved by Western Union in preparing the new transcontinental microwave system for operation. Avoidance routing, efficient use of available RF channel spectrum, and data transmission were some of the keypoints on which the system was designed.

This article is condensed from a paper presented at the 16th Annual Convention of the Armed Forces Communications and Electronics Association in Washington, D.C. in June 1962.

Announcements
Awards

1962 d'Humy Medalist—W. D. Buckingham

Western Union TECHNICAL REVIEW, VOL. 16, No. 4 (Oct. 1962), pp 180

This is an announcement of the presentation of the 1962 d'Humy Award to Mr. W. D. Buckingham "for his original ideas, fruitful research and inventions in many areas of communications and national defense."

Test Instruments
Carrier Equipment

Dot Generator 10699-A—Product release

Western Union TECHNICAL REVIEW, VOL. 16, No. 4 (Oct. 1962), pp 184

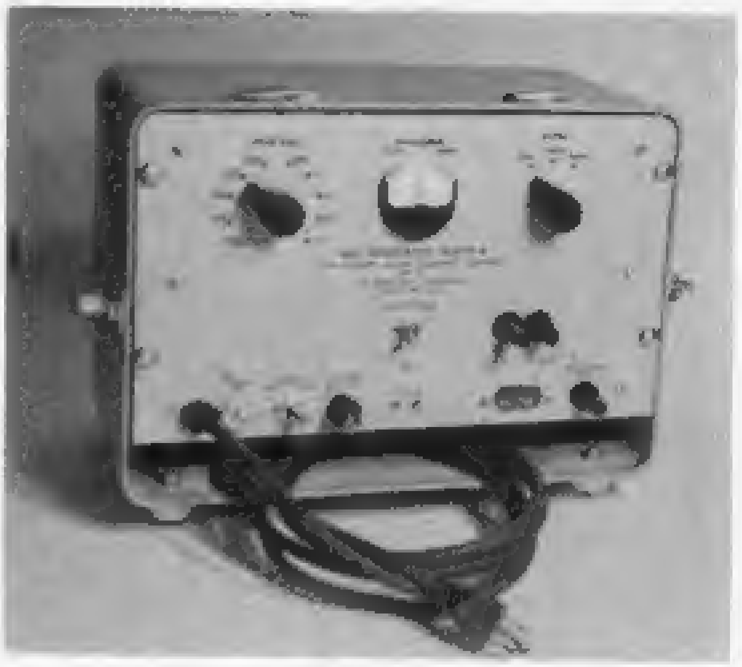
This is a product release on an instrument designed to produce zero bias square waves, of various baud rates, for testing and regulating data carrier equipment. A limited number of these units, manufactured in the Water Mill Laboratory are available for field use.

Dot Generator

THE Dot-Generator 10699-A is a portable instrument designed to produce zero bias square waves, of various baud rates, for testing and regulating data carrier equipment. It is controlled by a crystal oscillator from which a series of speeds ranging from 75 to 2400 bauds is provided by means of digital techniques.

The instrument generates steady mark, steady space or a-c signals (1:1 reversals) square-wave timing is available for use with synchronous 2400-baud modems. A meter is provided to measure current in the sending leg to the modem equipment.

The Dot Generator is now being manufactured in the Water Mill Laboratory. Over 200 units will be available for field service.



* * * * *

COMING EVENTS—in Future Issues

The following articles will be included in future issues of the Western Union TECHNICAL REVIEW:

Bomb Alarm—Display System 210-A . . . . by W. D. Buckingham and C. R. Deibert

Measurement of Discontinuities in Waveguides . . . . . by E. Aronoff

Data Card Transmitter 11313-A . . . . by P. F. Recca

Switching System—Plan 39 . . . . by R. J. Duswalt

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